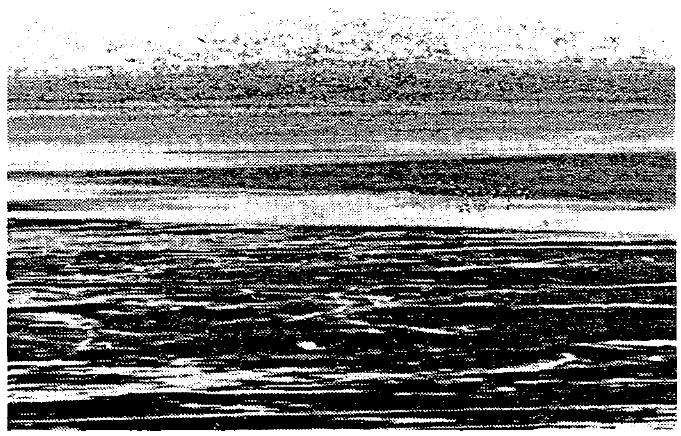
Response of Pacific Black Brant and Other Geese to Aircraft Overflights at Izembek Lagoon, Alaska

1987 Annual Report



Alaska Fish and Wildlife Research Center

1987 ANNUAL REPORT

RESPONSE OF PACIFIC BLACK BRANT AND OTHER GEESE TO AIRCRAFT OVERFLIGHTS AT IZEMBEK LAGOON, ALASKA

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Key Words: Black brant, emperor geese, Canada geese, distribution, aircraft noise, aircraft disturbance, Izembek Lagoon, Alaska Peninsula

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SUMMARY

Response of Pacific black brant (Branta bernicla nigricans) to aircraft overflights was studied at Izembek Lagoon, Alaska. The goals in 1987 were to continue assessment of aircraft disturbance, particularly helicopters, on geese and to initiate a new study to measure aircraft noise and relate this to the behavioral response of brant. We also continued studies of undisturbed brant in Izembek Lagoon to investigate their abundance, distribution, and movements.

Potential disturbances, mostly aircraft, did not change from other years of this study, occurring at a rate of 1.4/h of observation. The response of brant was greatest to the Bell 205 helicopter, and unlike responses to other aircraft types, intensity of the response by brant did not decrease as altitude of the Bell 205 increased up to 762 m (2,500 ft). The initiation (distance of response) and magnitude of the behavioral response by brant corresponded closely to the measured intensity of noise generated by the Bell 205.

<u>Abundance and distribution</u>. Fall staging by geese was initiated at a similar date as in 1986 (Ward et al. 1987). Immigration of brant occurred throughout September with peak numbers present from late September to late October. Peak number of 150,500 brant at Izembek Lagoon was the highest since 1984. Brant were distributed throughout the entire lagoon, but were concentrated at the southern end of the lagoon during the period of peak numbers. Their distribution was not related simply to the amount of eelgrass (Zostera marina), but seemed to be related to a combination of factors that could include nutrient quality or availability of eelgrass. Approximately 9,000 brant remained at Izembek Lagoon in November, 1987, which is a larger population of over-wintering birds than has occurred since 1982.

Peak number of 44,300 Canada geese (Branta canadensis taverneri) in 1987 did not differ from the peak in 1986. Canada geese were widely distributed throughout the lagoon. All Canada geese departed Izembek at the same time as brant.

Immigration of emperor geese (Chen canagica) paralleled the arrival of brant. Peak number of 7,300 emperor geese was the highest since 1984. Emperor geese differed in distribution from brant and Canada geese by primarily using the northern portion of the lagoon, especially the barrier islands.

<u>Response to aircraft</u>. As in other years of the study, aircraft (54%) and hunters (6%) were the most frequent human-related causes of disturbance, and bald eagles (Haliaeetus leucocephalus) (24%) were the most important natural disturbance. Mean number of incidental disturbance events per hour of observation in 1987 (1.4/h) was similar to other years: 1986 (1.3/h) and 1985 (1.6/h).

Preliminary data analysis for 6 types of aircraft was initiated to define the zone of influence for each stimulus as defined by altitude and lateral distance to the flock, and to determine the relative importance of other factors influencing the disturbance response. Response of brant to single-engine and multi-engine airplanes was decreased by both greater

altitude and greater lateral distance. Response to helicopters was decreased with greater lateral distance, but response was either slightly influenced (Bell 206-B) or actually increased (Bell 205) at greater altitude. Behavioral response by brant to twin-engine or jet aircraft stimuli was poorly predicted by the regression model.

Acoustics of aircraft. The Bell 205 helicopter produced considerably louder noise than any other aircraft based on a comparison of sound energy levels of 3 categories of aircraft (single-engine airplane, small and large helicopters). It generated approximately twice the noise of a smaller Bell 206-B helicopter and was 4 times louder than a small Piper 150 airplane. The noise generated by the Bell-206-B Jet Ranger helicopter did not differ from a Cessna 206 single-engine airplane. The noise of the aircraft generally attenuated with increased altitude and lateral distance to the microphone. However, the amount of noise attenuation decreased and some cases increased at combinations of increased altitude and greater lateral distance. This phenomena was present for all aircraft, but was most apparent with the Bell 205 helicopter.

Behavioral response of brant at various combinations of aircraft type, lateral distance, and altitude was highly correlated ($R^2 = 0.80$) with noise level. Distance of initiation of response was farther and magnitude of response was greater for the Bell 205 helicopter than for any other aircraft. Estimated threshold for response in brant to aircraft noise appears to occur at or above a sound exposure level (SEL) of 65 decibels in A-weighted scale (dBA) or maximum instantaneous noise (L_{max}) of 60 dBA. This is considerably lower than for other birds.

INTRODUCTION

Each spring and fall nearly the entire population of Pacific black brant stages at Izembek Lagoon near the western end of the Alaska Peninsula (Gabrielson and Lincoln 1959, Johnsgard 1975, Bellrose 1980, Izembek NWR 1986). During these staging periods brant feed exclusively on eelgrass. Izembek Lagoon contains one of the largest beds (17,868 ha) of eelgrass in the world (McRoy 1966). Importance of this lagoon to brant and other avian populations has led to its designation as a wetland of international importance under the RAMSAR (International Union for the Conservation of Wetland Habitats) convention.

Following migration from wintering areas along the Pacific coasts of North America, brant accumulate fat reserves during spring staging (April-May) at Izembek Lagoon. These reserves are important for egg production and incubation (Ankney 1984). Brant that were heavier than average on spring staging grounds in western Europe had an increased probability of returning the following fall with young (Ebbinge et al. 1982).

During fall staging (September-November), the entire population returns to Izembek Lagoon and adjacent estuaries to gain the necessary fat reserves for transoceanic migration to wintering areas. Male and female brant gained 13.2% and 10.5%, respectively, of their weight at Izembek Lagoon from September to October (D. Derksen unpubl. data). Stored lipids are the primary fuel for long distance flight in birds (Berger and Hart 1974, Blem 1980) and a major determinant of the potential distance an avian migrant can fly without stopping (Nisbet et al. 1963, Child 1969, Blem 1980). Transoceanic migration of brant is believed to be a direct flight of 5,440 km (3,400 mi) from Izembek Lagoon to Mexico (Kramer et al. 1979).

Incidental observations in fall 1984, indicated that brant, Canada, and emperor geese were apparently disturbed by helicopter overflights associated with Outer Continental Shelf petroleum exploration (J. Sarvis and C. Dau pers. comm.). Increased aircraft traffic over the lagoon may be detrimental to the ability of brant to store sufficient reserves for reproduction and migration. Location of petroleum industry support facilities at Cold Bay would also bring increased human population and more recreational activities such as hunting, boating, or aviation on or near the lagoon. These factors may result in additional stress for staging geese.

Disturbance by aircraft reduces brant foraging efficiency by causing interruptions in feeding bouts (Derksen et al. 1979, Simpson et al. in prep.), displacement from preferred habitats (Owens 1977, Kramer et al. 1979, Henry 1980), and possibly an increase in energy expenditure due to escape-related activities, as occurred in snow geese (*Chen caerulescens*) (Davis and Wisely 1974). The energetic cost of the response by brant at Izembek to increased frequency of rotary- or fixed-wing aircraft is unknown.

Past studies have shown that brant are one of the waterfowl most sensitive to human disturbance. Within the past 50 years brant have shifted their winter range from the coasts of Washington, Oregon and California to estuaries of mainland Mexico and Baja California. This shift was caused, at least in part, by intensive human use of Pacific coast estuaries (Denson and Murrell 1962, Einarsen 1965, Smith and Jensen 1970, Chattin 1970, Henry 1980). On the North Slope of Alaska, aircraft were the most frequent cause of disturbance to molting brant (Derksen et al. 1979, Simpson et al. in prep.). Simpson et al. (in prep.) found that aircraft overflights prevented flightless brant from feeding 2.4% of the time. On the North Slope and Yukon Territory, Davis and Wisely (1974) demonstrated that experimental overflights by fixed-wing aircraft caused staging snow geese to decrease feeding time by 8.5% which could result in a 20.4% reduction in energy reserves.

OBJECTIVES

Objectives of this research are to: 1) determine the effect of aircraft overflights and other human activity on behavior, distribution, and habitat use of brant at Izembek Lagoon, and 2) evaluate the potential impact of disturbance on the energetic of migration and reproduction of geese. An additional objective was initiated in 1987 to: 3) record and examine noise associated with incidental and experimental aircraft overflights.

This progress report summarizes a portion of the information collected in fall of 1987. The report is organized into three sections that reflect the main areas of data collection this year. These are: 1) quantification of the timing of arrival and departure, abundance, and distribution of brant, 2) evaluation of behavioral response of geese to aircraft overflights and other disturbances, and 3) examination of noise levels associated with aircraft overflights.

STUDY AREA

The study was conducted at Izembek Lagoon, Alaska (55°15'N, 163°00'W) on the north side of the Alaska Peninsula (Figure 1). The lagoon is about 48 km (30 mi) long and varies in width from 3-10 km (2-6 mi). Approximately 78% of the lagoon is intertidal, of which 68% is vegetated by eelgrass (Barsdate et al. 1974). Tides are both semidiurnal and mixed semidiurnal with a mean range of 0.98 m (3.2 ft) MLLW (mean lower low water)(U.S. Dept. of Commerce 1987). Tundra adjacent to the lagoon is generally flat to gently rolling, but in some areas, shoreline bluffs attain elevations exceeding 20 m (66 ft). Dominate shoreline vegetation is beach rye grass (*Elymus arenarius*)*

The climate of Izembek Lagoon is maritime but becomes more continental in winter when ice covers portions of the Bering Sea (McRoy 1966). Weather is characterized by high winds (mean annual velocity of 27 kph), moderate and stable temperatures (mean annual fall temperatures of 4-7 C), long periods of cloud cover (83% average cloud cover for any 24 h period in fall) and frequent precipitation (mean annual precipitation of 89 cm) with most occurring as rain in the fall (U.S. Department of Commerce).

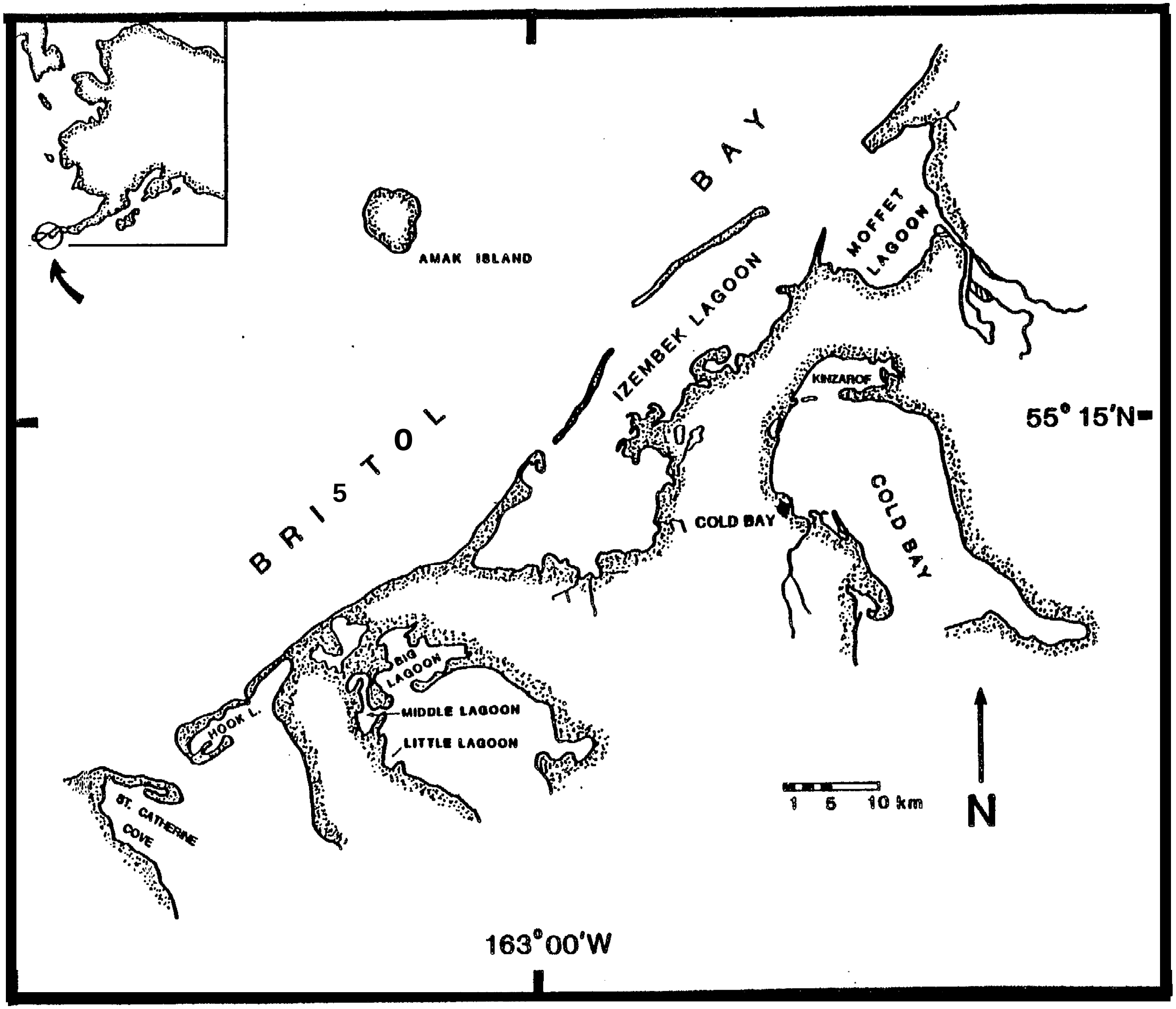


Figure 1. Location of Izembek Lagoon including Moffet Lagoon, Kinzarof Lagoon, Big, Middle and Little Lagoons, Hook Lagoon, and St. Catherine Cove on the Alaskan Peninsula.

ABUNDANCE AND DISTRIBUTION OF GEESE IN IZEMBEK LAGOON

INTRODUCTION

An understanding of spatial and temporal patterns of habitat use is essential to evaluate potential effects of increased aircraft activity on brant and other geese at Izembek Lagoon. Such data will provide a basis for assessing displacement of geese, if it occurs, from previously occupied areas of the lagoon. Also, these data can be used to establish management recommendations to minimize the effects of aircraft overflights by establishing flight corridors over habitat areas that are least important to geese, or by determining time periods when overflights will have minimum influence.

Counts of geese at Izembek Lagoon have been made by the staff of Izembek National Wildlife Refuge (INWR) for over 28 years. Prior to 1975, these counts relied on estimates from ground observations and were primarily conducted during fall migration. Since that time, aerial surveys have been flown at Izembek and adjacent estuaries to count geese during both spring and fall migration at the time of peak numbers of brant. Timing of these aerial surveys coincided with peak numbers of brant and data represent only the total numbers of birds at that time.

We intensified efforts in fall of 1987 to determine the phenology of migration and pattern of habitat use at Izembek Lagoon. We initiated observations of geese earlier in the fall and increased the number of aerial surveys.

METHODS

Environmental conditions. Wind speed and direction, cloud cover, and visibility were estimated and recorded at each study site every hour during the observation period. Tide levels were measured at each study site by recording the length of a PVC pipe marked in 0.15 m (0.5 ft) increments that remained above water level. A 'continuously recording tide gauge was also established at Grant Point as a reference for gauges at the blinds (Figure 2). A permanent National Weather Service station (WSO) at Cold Bay provided all other weather information.

Abundance. Distribution and Habitat Use. Ground observations of geese were initiated on 20 August and continued through 17 November. Before and after this period, staff of INWR watched for early arriving and late departing geese. Geese were observed from 1 September to 2 November from 8 locations along the shoreline of Izembek Lagoon (Figure 2). Seven sites, Applegate Cove (AC), Norma Bay (NB), Banding Island (BI), Grant Point-west (GW), Grant Point-east (GE), Halfway Point (HP), and Round Island (RI) were in or near the same locations as in 1985 and 1986. The blind at the east end of Round Island was moved from the 1986 location to a new position at Outer Marker (OM).

Observations were made from blinds 1-5 days per week for up to 12 h per day. Time and date of occupancy varied for each blind site depending on weather, use of the area by geese, and timing of experimental overflights.

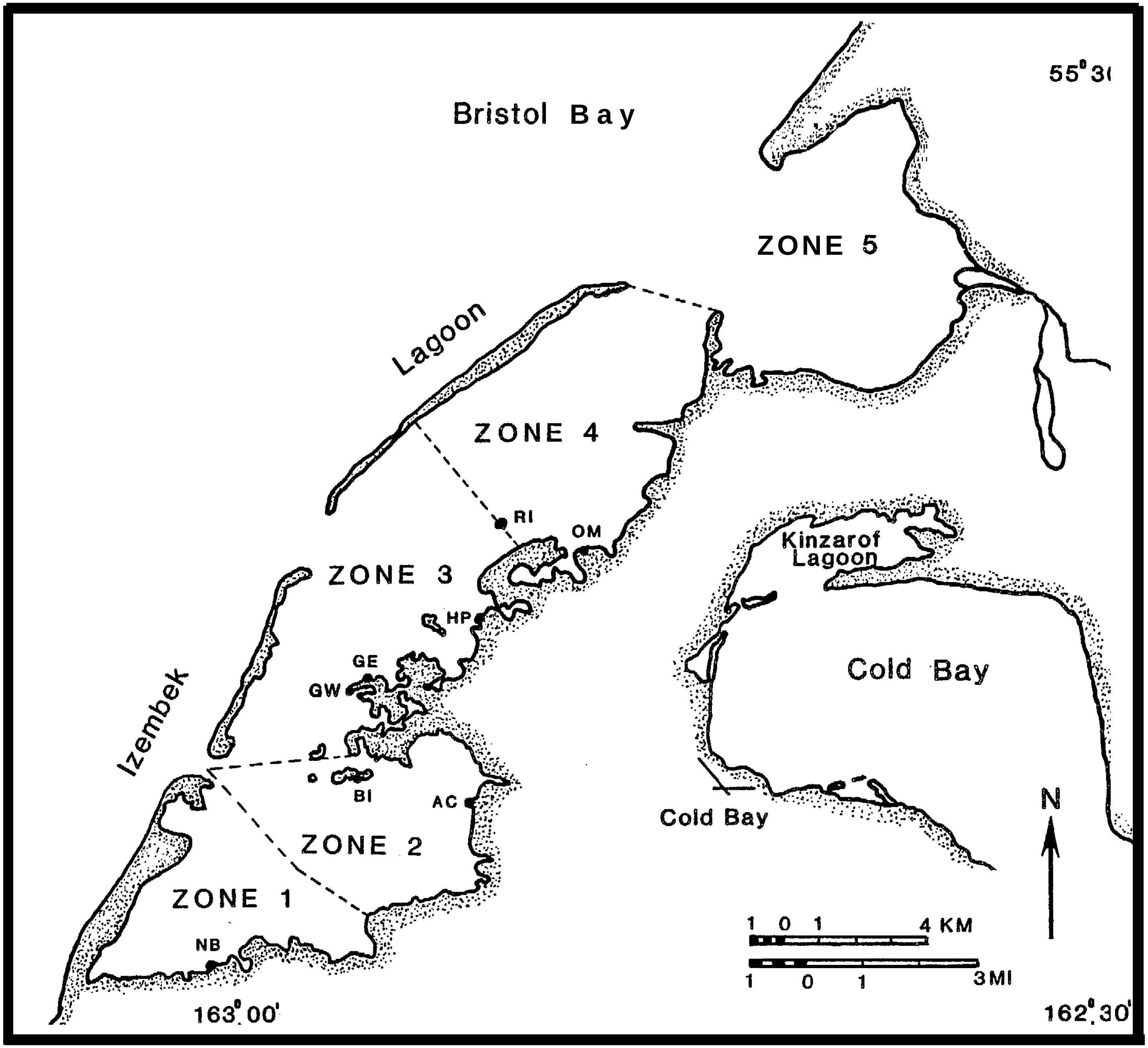


Figure 2. Location of blinds and 5 zones used to delineate the distribution of geese during aerial surveys at Izembek Lagoon, Alaska, fall 1987. Blinds include: Norma Bay (NB), Applegate Cove (AC), Banding-Island (BI), Grant Point-West (GW), Grant Point-East (GE), Halfway Point (HP), Round Island (RI), and Outer Marker (OM).

The field of view from each blind defined each study area. A study area did not extend beyond a distance of approximately 1.2 km (0.75 mi), although distances varied and were influenced by the elevation of the blind about the lagoon and observers' ability to see and accurately identify species, age and numbers of geese. Each study area was delineated by bouys, natural landmarks, and channels.

Total number and distribution of geese were determined during aerial survey counts . Seven surveys were flown by personnel from the Office of Migratory Bird Management or INWR between 3 September and 27 November. All aerial surveys, except on 27 November, included the entire complex of Izembek Lagoon, St Catherine Cove, Hook Lagoon, Big, Middle, and Little Lagoon, and Kinzarof Lagoon (Figure 1). The survey on 27 November included only Izembek and Kinzarof Lagoons. Because of the possible influence of tide on the distribution of geese during counts, surveys were performed during a similar tidal height (high tide). Two early surveys on 3 and 22 September, however, were made at low and moderate tidal heights, respectively but these counts were not thought to have been biased and were included for comparison. Surveys were flown in a Piper 150 or Cessna 206 at an altitude of 76 m (250 ft) and an airspeed of 90 kts (160 kph). The course flown varied among surveys and pilots. Two experienced observers, including the pilot, counted geese and located them in areas of the Izembek complex. Locations of geese within Izembek Lagoon were further divided within zones (Figure 2) as was done in 1986 (see Ward et al. 1987).

Distribution and size of 3 primary habitat communities (eelgrass, mud flat and water) were determined from a 1978 LANDSAT image of Izembek Lagoon taken at low tide -0.2 m (-0.7 ft) (MLLW) (Table 1). Interpretation of the image was provided by USGS/EROS Field Station, Anchorage, Alaska. Habitat classification was subjectively verified by comparing the LANDSAT image with observations and field notes recorded on habitat. Although complete verification of the habitat classes has not been undertaken, it appears the image is representative of the lagoon.

RESULTS AND DISCUSSION

Environmental conditions. Weather patterns in fall 1987 were more inclement than the mild fall of 1986. Precipitation was above normal in September and October, and measurable quantities were recorded almost daily at Cold Bay WSO (Table 2). Precipitation was in the form of rain (or rarely sleet) until 24 October. On 3 November rain turned to snow, and virtually all precipitation after that (except on 14 and 15 November) was snow.

Mean wind speeds for September and October were over 27 kph (15 kts), and peak gusts averaged near 64 kph (35 kts). Winds were predominately from the NW. Cloud cover ranged from 79-91% during the study period. Ceilings typically were 305 to 610 m (1,000 to 2,000 ft) although they changed during the course of the day and varied locally.

Monthly temperature averages ranged from above normal in late August and October to below normal in November (Table 2). Small lakes and ponds began freezing on 25 October. Large lakes froze and reopened several times during the first half of November. Moffett Lagoon was a mosaic of open water, slush,

Table 1. Area in hectares and proportion of Izembek lagoon total within each of 5 zones of the 3 primary habitat components based on interpretation of a 1978 LANDSAT image.

Habitat	Hectares (proportion) within zones					Total
	1	2	3	4	5	
Eelgrass	3121 (.199)	3248 (.207)	2874 (.183)	4446 (.283)	2006 (.128)	15,597
Mud	735 (.059)	658 (.053)	3864 (.308)	1674 (.134)	5595 (.447)	12,526
Water	394 (.065)	1149 (.189)	1112 (.183)	1623 (.267)	1800 (.296)	6,079
Totals	4250.0 (.124)	5055.5 (.147)	7851.0 (.229)	7743.5 (.226)	9401075 (.274)	34,302

Table 2. Summary of weather conditions at Cold Bay, Alaska, 20 August - 30 November, 1987. Source: Cold Bay WSO.

	August[a]	September	October	November
Temperature (°C)				
Mean maximum	15.8	10.6	8.1	1.4
Mean minimum	8.3	5.9	1.9	-3.7
Mean mean	12.1[b]	8.3[c]	5.0[b]	-1.1[d]
No. days with:				
Fog	11	15	8	2
Measureable rain	2	25	29	6
Measureable snow	0	0	1	17
Total precipitation (mm)	3d	106[b]	140[b]	7gd
Wind				
Mean velocity (kph)	15.4	28.7	27.4	24.1
Mean peak gust (kph)	41.5	62.6	60.0	50.5
No. days mean velocity				
Less than 16.1 kph	5	1	3	9
Greater than 32.2 kph	1	10	11	6
Greater than 48.4 kph	0	2	0	1
No. days wind from				
Northeast	1	1	1	4
Southeast	3	6	10	2
Southwest	0	7	10	5
Northwest	8	16	10	19
Mean cloud cover (%)	79	91	83	81
No. days rated:				
Clear	1	0	0	2
Partly cloudy	3	4	8	8
Cloudy	8	26	23	20

a Includes data from only 20-31 August.
[b] Above average.
[c] Near average.
[d] Below average.

and skim ice on 7 November, while all other parts of Izembek Lagoon remained free of ice.

Population assessment. Brent were first observed at Izembek Lagoon on 14 August. During the week following 20 August, based on incomplete ground observations, brant increased from initial estimates of 150-350 to 5,000 by 27 August. Initiation of fall immigration of brant to Izembek Lagoon in mid to late August was typical of previous fall arrival dates (Hanson and Nelson 1957, Izembek NWR 1986, Ward et al. 1987). The first complete aerial count of brant within the Izembek complex occurred on 3 September when 18,701 birds were counted (Figure 3). Immigration was concentrated (62% of total) over a 19 day period (3-22 September) with noticeable influxes of brant occurring on 4 and 8 September. Brant continued to increase in September with an estimated peak of 150,515 recorded on 9 October.

Number of brant in 1987 (150,515) was the highest since 1984 (116,171) and 31% above the mean of 4 peak counts between 1984 and 1987 ($\bar{x}$ = 115,204; range 93,244 - 150,515) (Conant et al 1984, C. Dau unpubl. data). The increase of brant in 1987 was related in part to extremely high nest success (90%) of brant on the Yukon-Kuskokwim Delta (Stehn 1987), where approximately a third of the Pacific black brant nest, and a high number of juveniles (31%) in the fall population of brant at Izembek Lagoon (Sarvis 1987).

Departure of brant was first observed on 21 October, but the majority of the emigration occurred on 3 and 5 November when 93,000 and 31,000 geese left, respectively. Not all brant (9,355) had departed by the last aerial survey (Figure 3) and these birds may represent an overwintering population. Brant have historically wintered at Izembek Lagoon in low numbers (ea. 100) (C. Dau pers. comm.). Recently (1981-86), however, an average of 3,800 brant have overwintered, with a peak count of 9,860 in 1982 (C. Dau unpubl. data). Mild winters in the 1980's may have contributed to the increased number of brant remaining for winter.

The numbers of brant surveyed in January were 138,600 on wintering grounds in Mexico, California, Oregon, and Washington (J. Bartonek unpubl. data) and 8,385 within the Izembek complex. The total of these two winter counts of 146,985 brant compares well with the peak count of brant (150,515) found during fall staging within the Izembek complex. This comparison gives credance to the theory that the Izembek complex supports nearly all the Pacific Flyway brant during fall staging (Conant 1987).

Canada geese arrived on 23 August, a week later than brant. Numbers of Canada geese increased in September and early October, but did not reach peak numbers (44,261) until 28 October, nearly 3 weeks after peak numbers of brant (Figure 3). A delayed peak number of Canada geese was also observed in fall, 1986 (see Ward et al. 1987), but it is not clear whether these counts represent an actual delay in arrival of Canada geese to Izembek Lagoon or incomplete coverage of areas used by Canada geese during aerial surveys. Canada geese use both tidal and adjacent tundra areas but only those birds found intertidally were counted. Incomplete counts may have occurred during high tides when Canada geese were most likely to use tundra habitats, and also, early in the season when crowberry (*Empetrum nigrum*) and lingonberry (*Vaccinium vitis-idaea*) are abundant (Jones in prep.).

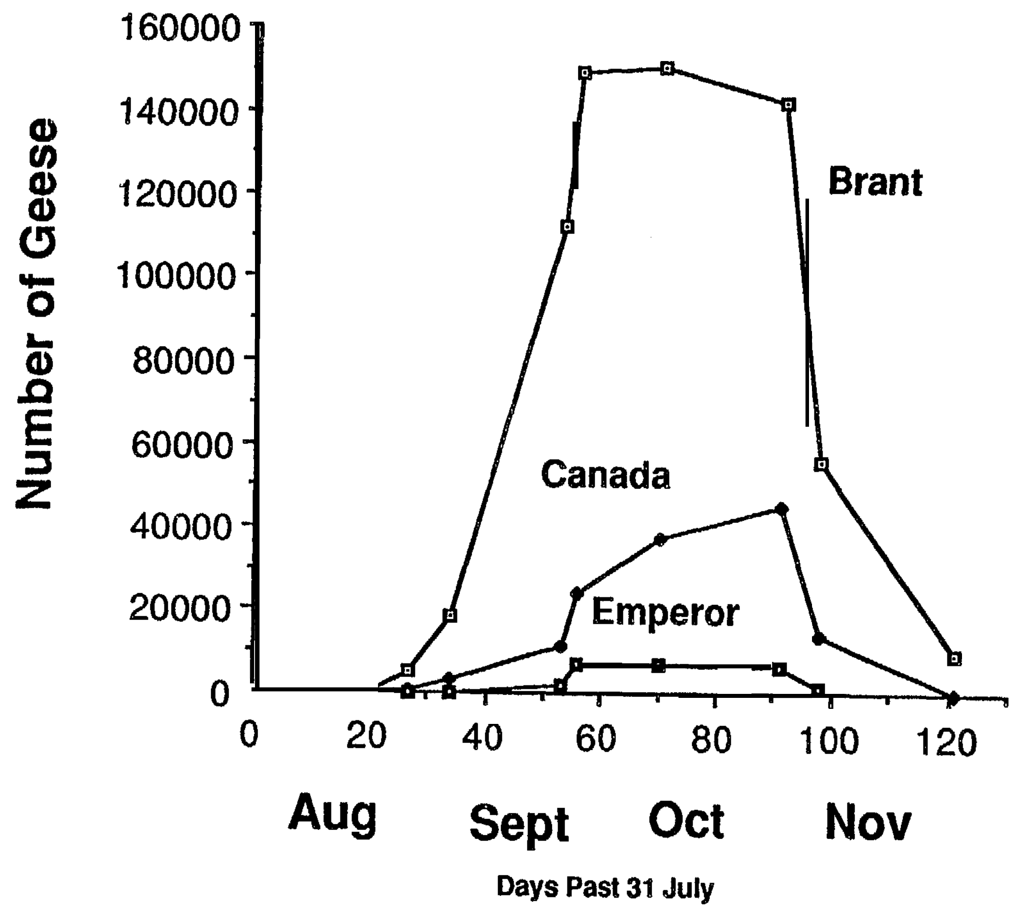


Figure 3. Numbers of brant, Canada and emperor geese recorded during aerial surveys of Izembek Lagoon and adjacent lagoons, Alaska, fall 1987.

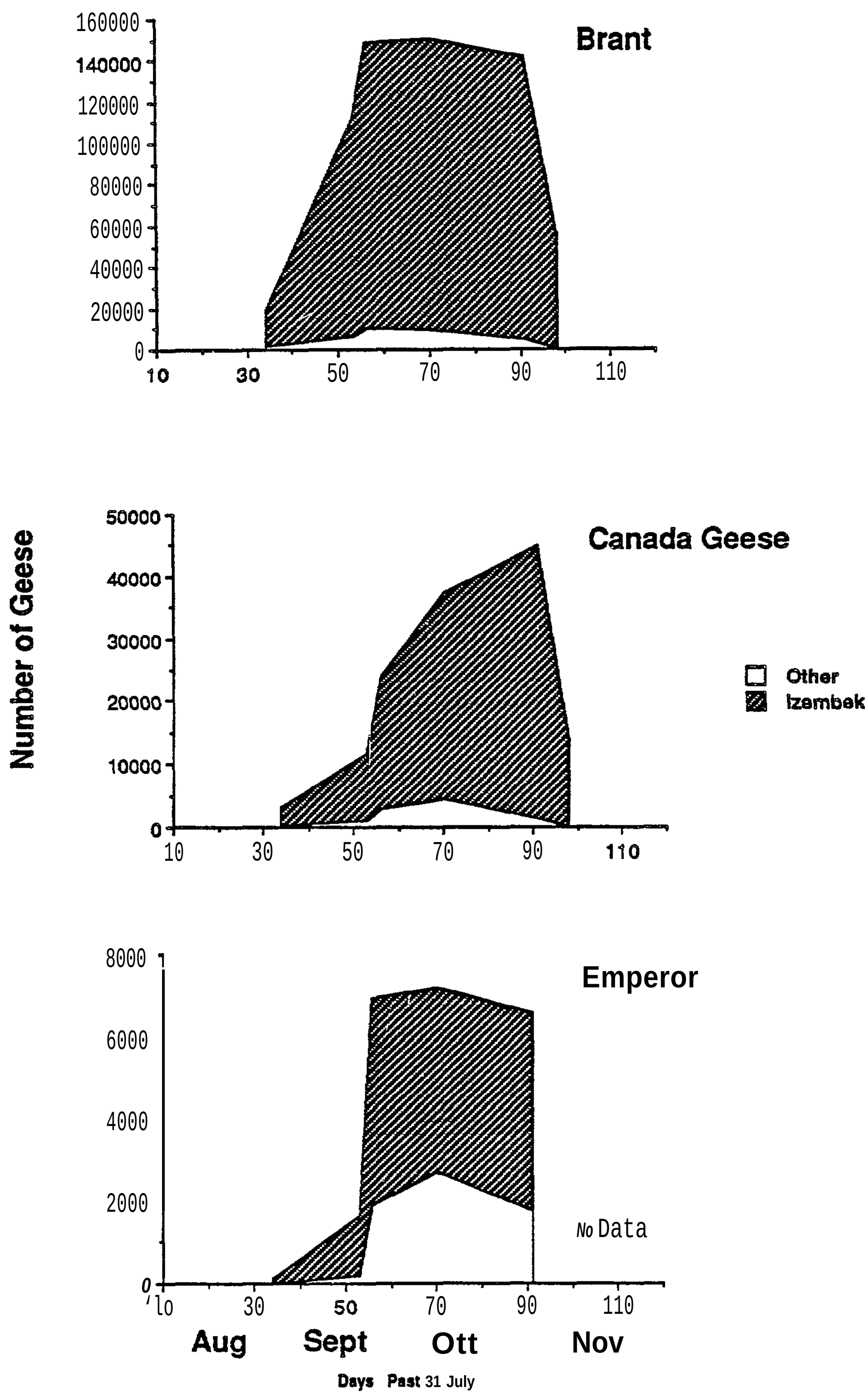


Figure 4. Number and proportion of brant, Canada and emperor geese observed during aerial surveys between 3 September and 4 November within Izembek Lagoon (Izembek) and adjacent estuaries (other), Alaska, fall 1987.

Table 3. Number of brant, Canada, and emperor geese observed during aerial surveys within five zones of Izembek Lagoon, Alaska, fall, 1987.

	Zone	Date of Survey					
		3 Sept	22 Sept	25 Sept	9 Ott	28 Ott	4 Nov
Brant							
	1	1,980	32,153	35,309	18,226	46,425	14,230
	2	3,560	26,270	31,198	51,642	35,275	8,765
	3	6,925	12,057	38,898	41,315	23,923	8,850
	4	1,953	24,064	11,090	11,788	19,980	19,270
	5	2,788	10,975	22,522	18,170	11,557	4,500
Totals		17,206	105,519	139,017	141,141	137,160	55,615
Canada							
	1	0	2,312	2,837	5,095	7,905	775
	2	730	1,300	8,645	10,795	12,890	1,250
	3	0	526	1,277	2,425	675	5,500
	4	610	3,325	1,029	6,285	11,52'0	2,170
	5	1,380	3,080	7,357	8,175	10,625	4,140
Totals		2,720	10,543	21,145	32,775	43,615	13,835
Emperor							
	1	0	10	0	0	0	NS[a]
	2	0	0	0	0	5	NS
	3	0	60	1,269	955	1,572	NS
	4	20	465	630	150	62	NS
	5	72	912	3,185	3,402	3,236	NS
Totals		92	1,447	5,084	4,507	4,875	NS

[a] No survey.

The peak count of Canada geese in 1987 (44,261) was similar to the highest count in 1986 (45,022) (Ward et al. 1987) and only slightly lower than the mean of peak counts between 1984 and 1987 (45,418).

Departure of Canada geese coincided with emigration of brant. First departure of flocks of Canada geese was observed on 21 October and continued through November (Figure 3). The majority of the birds (approximately 21,000) left Izembek between 28 October and 4 November.

Emperor geese were first observed on 29 August. Timing of arrival for emperor geese coincided with brant with 68% of the population immigrating to Izembek Lagoon and adjacent estuaries between 3 and 22 September. Peak numbers (7,260) of emperors occurred on 9 October (Figure 3). Small numbers of emperor geese, less than 75 birds, were observed on tundra habitats, but these birds were not thought to have influenced counts during aerial surveys.

The peak count of emperor geese in 1987 was the highest recorded from 1984 to 1987 ($\bar{x}$ = 5,008; range 3,222-7,260). This increase may reflect the above-average nest success (93%) on the Yukon-Kuskokwim Delta (Stehn 1987) with a corresponding high number of juveniles (33%) in the fall population at Izembek Lagoon (Sarvis 1987). Large numbers of emperor geese (6$628) were still present on the last survey. It is usual for a small population (ea. 6,000) of emperor geese to winter in the Izembek complex.

Distribution. Izembek Lagoon was by far the most important single estuary used by geese in the area. It was used by 94% of the brant, 90% of the Canada, and 80% of the emperor geese (Figure 4). The predominant use of Izembek Lagoon is well documented (Conant et al. 1984, Izembek NWR 1986).

Seven aerial surveys (Table 3) and numerous ground counts in 1987 provided a more complete data set on goose distribution than available from previous years. Observed distribution in 1987 confirmed the patterns shown by less frequent surveys flown in 1986 (Ward et al. 1987), as well as replicate counts in 1984 (Conant et al. 1984). Brant were found in all zones in each survey with the majority using zones 1, 2, and 3 (Figure 5) from about 20 September to 20 October each year. During early and late periods of the fall staging period, the pattern of use by brant was different. Zone 3, near Grant Point, had the highest proportion of brant present early in September while zone 4, near Outer Marker, received predominant use late in October (Figure 5).

We compared the distribution of geese determined from aerial surveys conducted from 22 September to 28 October to habitat types of each zone (Table 4). Areas of eelgrass beds, mud flats, eelgrass plus mud, and total area within each zone were determined from LANDSAT classification and was expressed as a proportion of the total area of each category in the entire lagoon (Table 4). If the proportions of geese and of a given habitat type within a zone matched, we would conclude that coverage of that habitat type was correlated with abundance of geese. The 4 aerial surveys provided replicates. The ranked difference in the proportion of geese and the proportion of each habitat type was examined with a non-parametric Mann-Whitney test. If no significant departure was found from equal mean rank of the differences in proportions in each zone, we would accept the null hypothesis that goose abundance corresponded to coverage of that habitat type. The null hypothesis was rejected for all habitat components for all species. Predominate use of zones

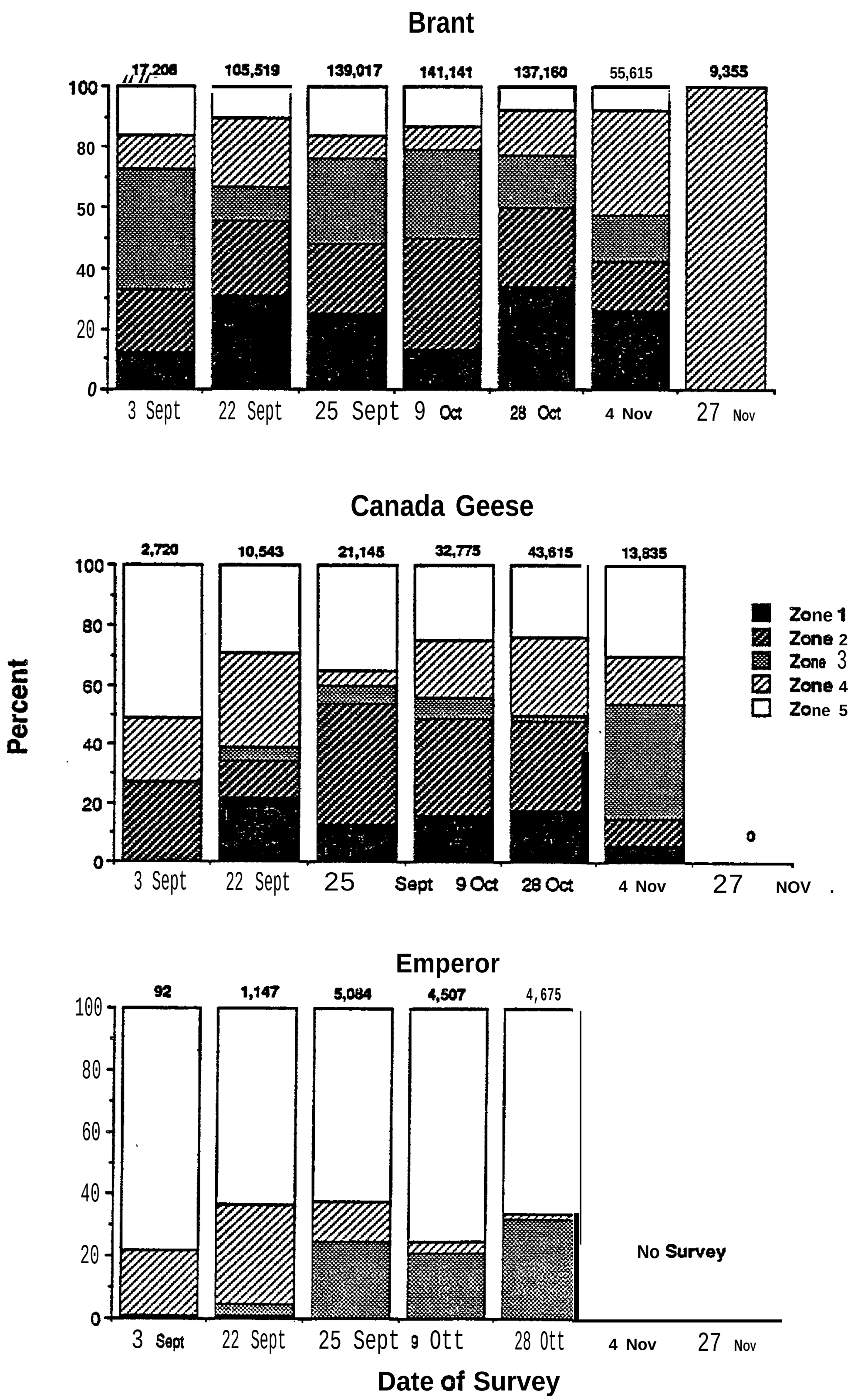


Figure 5. Percent of geese observed during aerial surveys within 5 zones of Izembek Lagoon, Alaska, fall 1987.

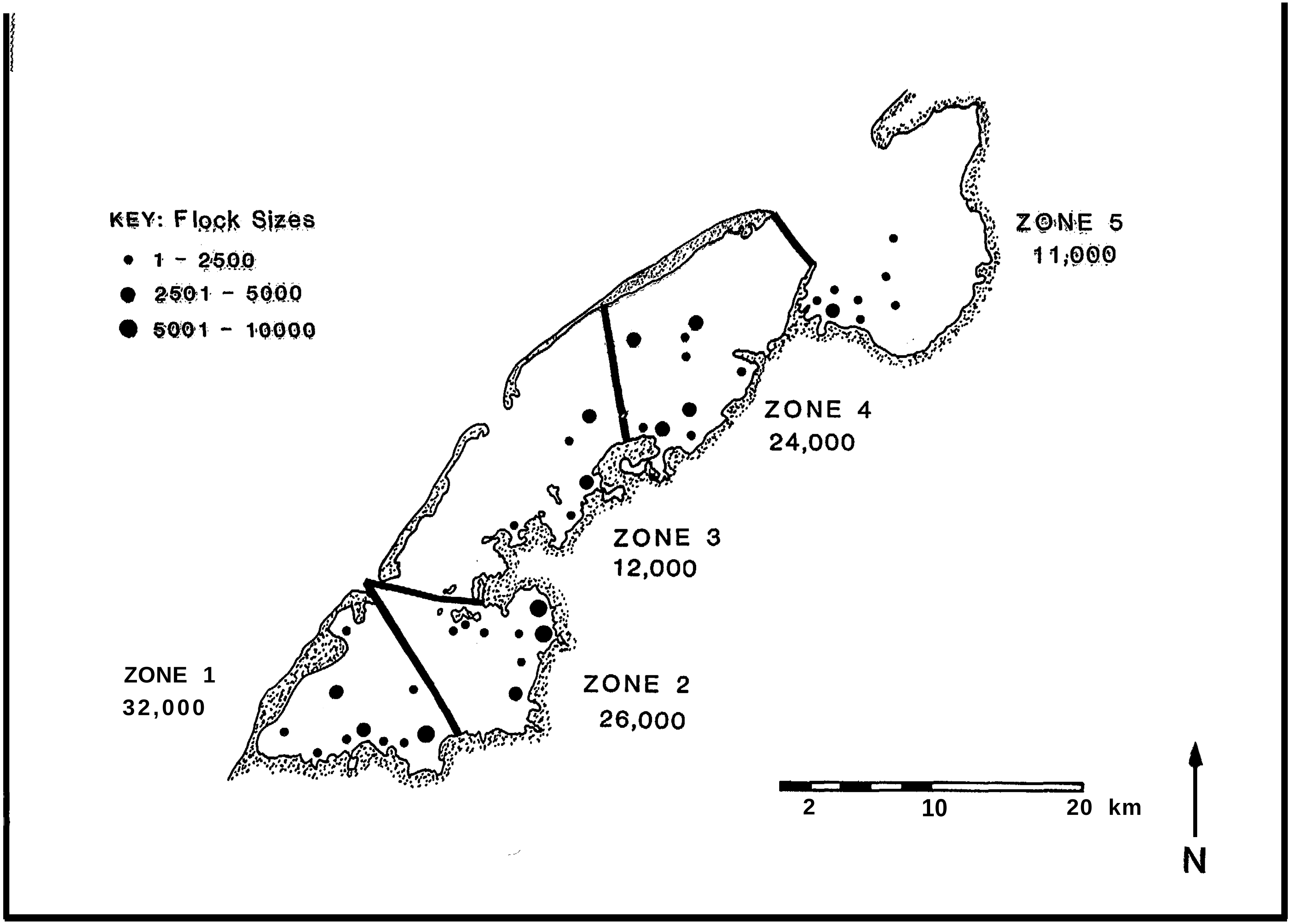
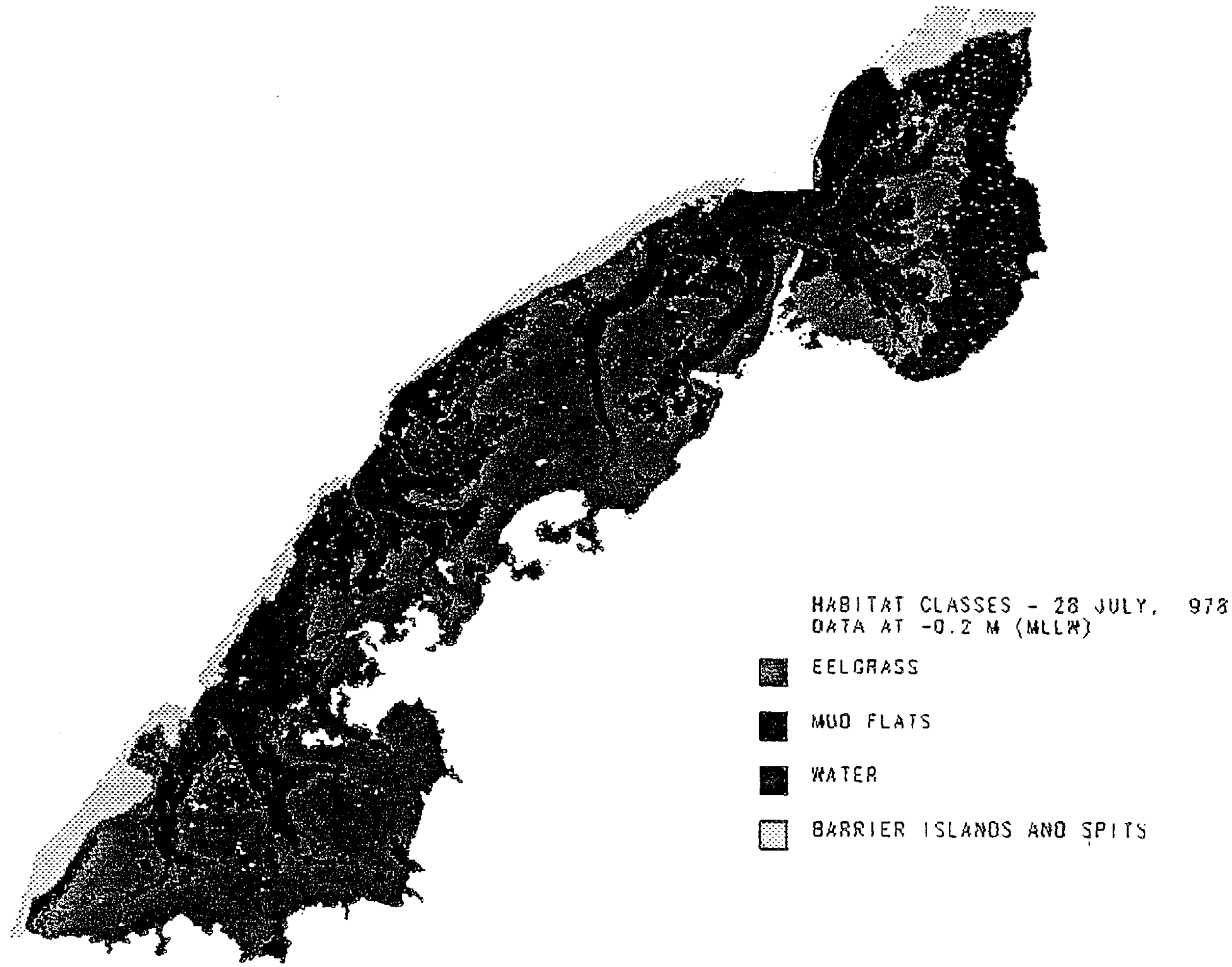


Figure 6. Distribution of brant during aerial survey at low tide, 22 September 1987, Izembek Lagoon, Alaska.

IZEMBEK LAGOON



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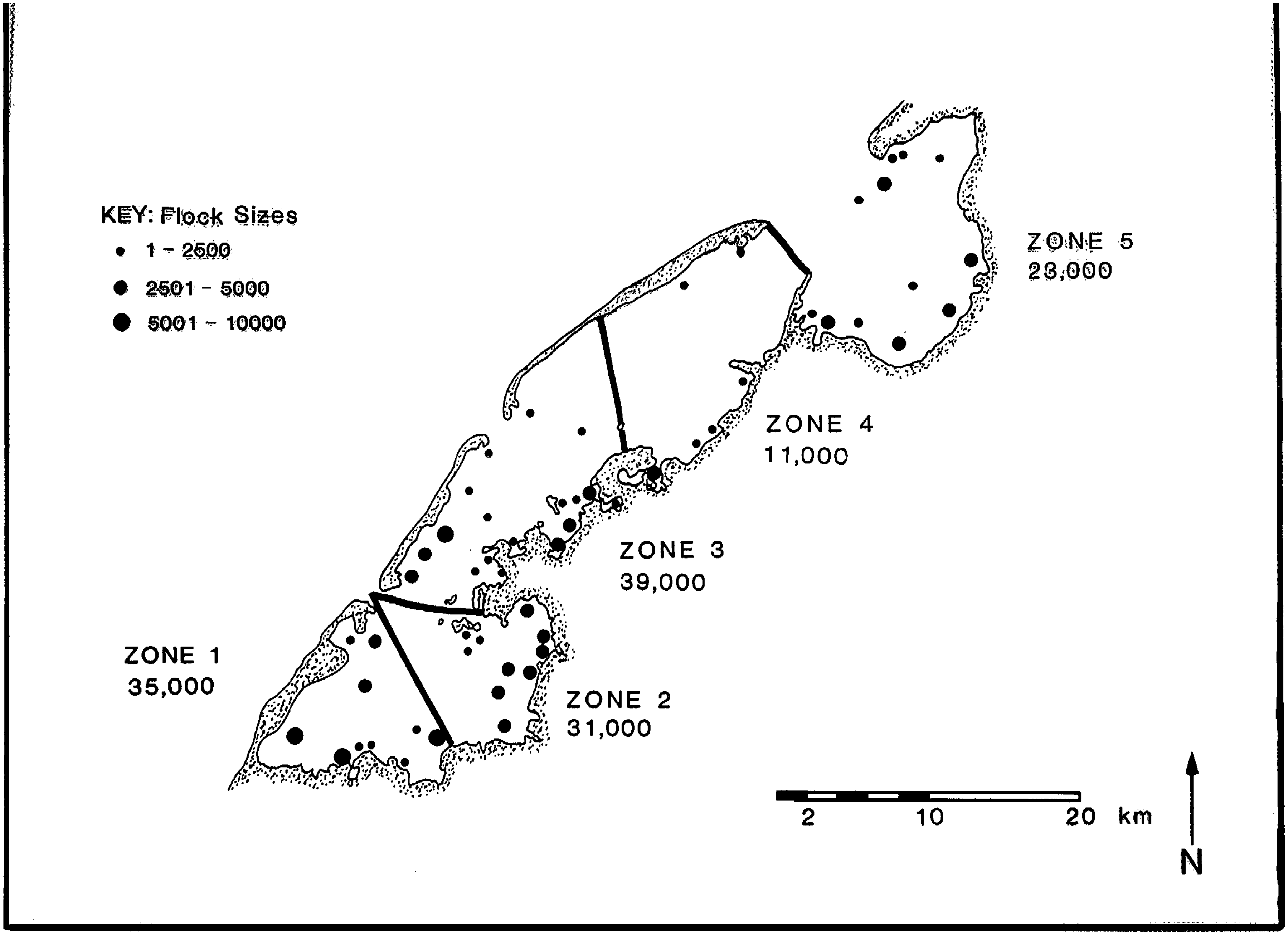
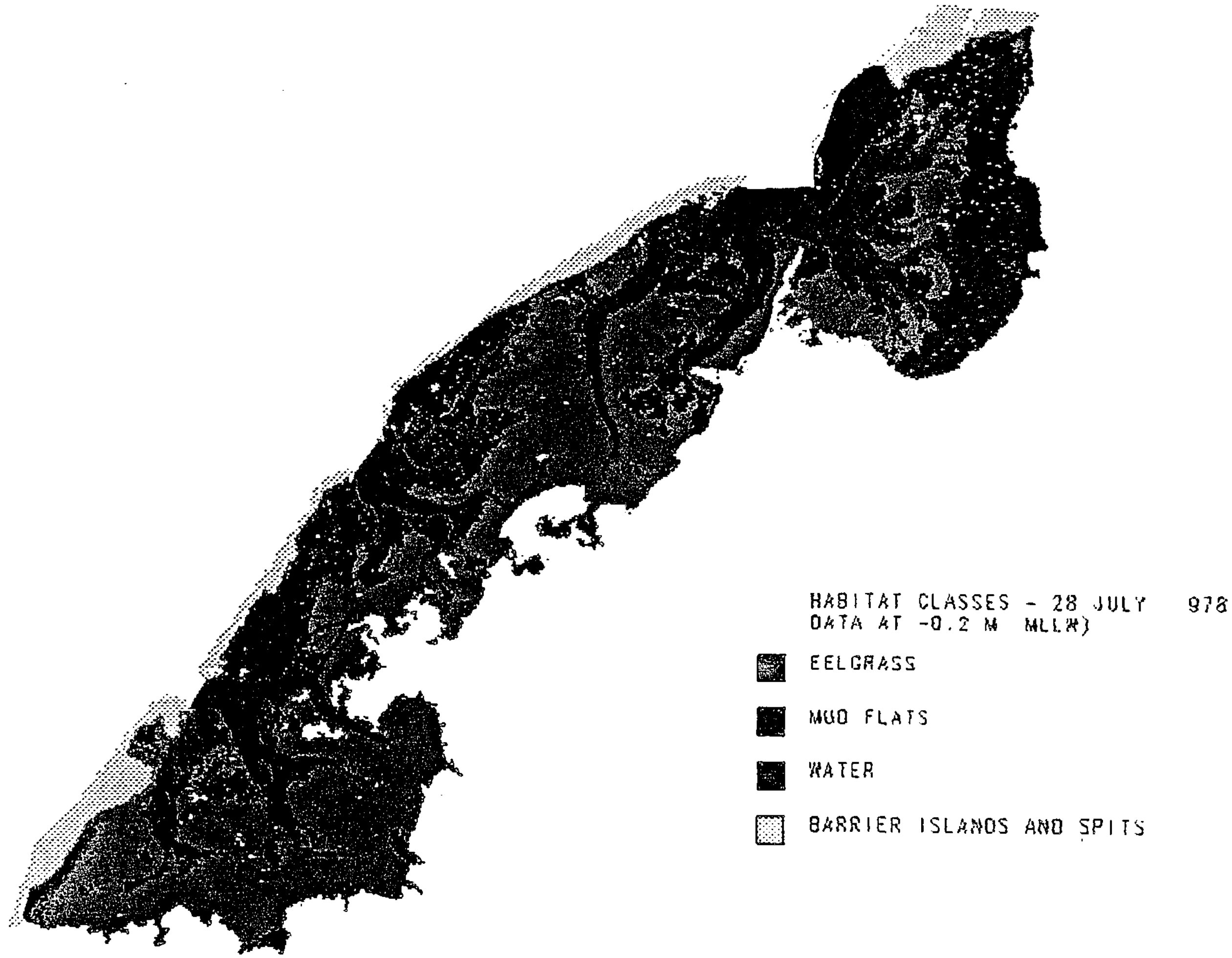


Figure 7. Distribution of brant during aerial survey at high tide, 25 September 1987, Izembek Lagoon, Alaska.

IZEMBEK LAGOON



DATA FROM DIGITAL ANALYSIS OF LANDSAT MULTISPECTRAL SCANNER
1978 SCENE 10-30145-2'103

Table 4. Distribution of brant (B), Canada (C), and emperor (E) geese during aerial surveys and habitat available among five zones of Izembek Lagoon, Alaska, Fall 1987.

	Percent of habitat available			Percent of birds in zones[b]		
zone	Eelgrass	Mud	Total	B	C	E
1	19.9	5.9	12.4	25.3	16.8	0.1
2	20.7	5.2	14.7	27.6	31.1	0.0
3	18.3	30.8	22.9	22.2	4.6	24.2
4	28.3	13.4	22.6	12.8	20.5	8.2
5	12.8	44.7	27.4	12.1	27.1	67.5

[a] Based on percent of primary habitat classes from 1978 LANDSAT imagery, excluding water.

[b] Based on the mean of 4 aerial counts of brant between 22 September and 28 October.

1, 2, and 3 and relatively few numbers of birds in zone 5 did not relate to abundance of any habitat types measured. From this we conclude that the nutrient quality, availability of eelgrass, or a combination of other factors (e.g. tides), is more important to brant than the coverage of eelgrass.

Within each of these large zones, we found the distribution of brant was directly influenced by tide. Figures 6 and 7 show a typical distribution of brant during low and high tide, respectively. During low tide, flocks of brant were dispersed widely and associated with eelgrass beds. Flocks are generally smaller and concentrated. During high tide brant were associated more frequently with mud flat areas, primarily located along the barrier islands. Those flocks found over eelgrass were generally larger and closer to shore than at low tide.

As was observed in 1986 (Ward et al. 1987), Canada geese were found in all zones, but their observed distribution within the lagoon based on aerial surveys is not complete (Table 4), because counts were made at high tide when Canada geese were more likely to be found on tundra habitat. In general Canada geese were found throughout all zones with zones 2 and 5 the most important areas.

Emperor geese were the least widespread (Table 4). They were concentrated in zones 3 and 5 and tended to use barrier islands and spits more frequently than other geese.

RESPONSE OF BRANT TO AIRCRAFT

INTRODUCTION

Disturbance associated with aircraft overflights may influence foraging behavior and energy balance of brant staging at Izembek Lagoon. Increased flight response from aircraft could prevent required intake of nutrients and cause increased metabolism of stored fat and other essential organic and mineral components necessary for migration. In order to evaluate the likelihood of these potential effects, it is necessary to describe the parameters of the disturbance stimuli that determine magnitude of response shown by flocks of brant.

A first step for understanding these parameters is establishing appropriate measures of disturbance response shown by brant and quantifying factors that influence this response. Behavioral observations from shoreline blinds have been made in September and October, 1985-1987. Frequency and extent of brant response to both incidental and experimental aircraft overflights have been recorded along with a series of covariables that may influence the response. Data analysis for 6 types of aircraft has been initiated and this report summarizes the preliminary results. Objectives of the analysis were to: 1) define the zone of influence for each stimulus in terms of altitude of aircraft and lateral distance to the flock, 2) compare responses elicted by various aircraft types, and 3) determine the relative importance of other factors (wind, direction of travel, flock size) influencing the disturbance response.

METHODS

All potential disturbances including aircraft, avian predators (e.g. bald eagle, falcon, _Falco spp._), mammalian predators (e.g. red fox, _Vulpes vulpes_, brown bear, _Ursus arctos_), humans on foot, boats, and gunshots were monitored within each study area. Aircraft overflights were categorized as incidental, if not related to our study, or experimental, if they were planned as part of the study and flown at controlled altitudes and known locations.

The behavioral response of geese to a disturbance was quantified using a rating system from Davis and Wisely (1974). In ascending order of energy expenditure these behavioral responses were:

1. no change,
2. alert - heads raised and increased intensity of calling (not often heard),
3. mass - swam into tight groups without flying,
4. fly - all flight. This category combines rise, circle, and depart responses (see Ward et al. 1986).

The percent of birds that exhibited each level of behavioral response was recorded for each individual flock observed in the study area.

For each potential disturbance event the following information was recorded: 1) cause of disturbance, 2) distance of the flock to the stimulus when the flock first reacted, or if there was no reaction, then the distance of closest approach, 3) altitude of aircraft, 4) social facilitation, 5) tide, 6) wind direction in relation to the flock and stimulus, 7) species, 8) flock size, 9) dominant behavior of the flock prior to the disturbance, 10) distance from the flock to the shore, 11) direction of the stimulus in relation to the flock (toward or lateral), 12) percent of the flock exhibiting each behavioral response category, 13) duration of flight if it occurred, and 14) total duration of the response. Flight duration was defined as the time required for 50% of the flock to land, and duration of the response was the time required for 90% of the birds to return to pre-disturbance behavior. Cassette tape recorders enabled us to describe the behavioral response and to determine response duration for several flocks during a single disturbance event. VHF radios were used to monitor communications between incidental aircraft in the vicinity and Cold Bay flight service. Knowledge of approaching aircraft and information on altitude, direction of travel, and weather conditions were gathered from conversations between pilots and Cold Bay flight service personnel.

With planned experimental flights, altitude and lateral distance of the aircraft to geese was controlled or measured quite accurately rather than estimated as for incidental aircraft flights. Four categories and 5 types of aircraft were used for experimental overflights: single-engine airplanes (Piper 150 and Cessna 206), multi-engine airplanes (Hercules C-130), small helicopter (Bell 206-B Jet Ranger), and large helicopter (Bell 205). Experimental flights were conducted on 11 days from 23 September to 18 October. Each flight had established flight paths, altitudes and velocities. All aircraft, except the Hercules C-130, were flown along 16 standardized lines, oriented to pass over study sites and maximize use of flight time (Figure 8). The Hercules C-130 did not follow the above lines but used other predetermined corridors (Figure 9) and in a few cases unscheduled aircraft radioed their flight line to an observation blind prior to a pass. With multiple overflights, altitude was usually decreased on successive passes (as in 1985 and 1986). This allowed more data to be collected before there was a substantial response by the geese. This protocol may cause problems in data interpretation if there is substantial habituation to aircraft stimuli. For this reason, the order of altitudes was randomly determined on some days in 1987. Table 5 summarizes the species and number of flocks observed during experimental overflights in 1987.

Various techniques were used during experimental overflights to better estimate distances and timing of responses by geese. Maps of each study site were drawn from black and white aerial photographs depicting experimental flight lines and start points for each flight line. To provide consistency of overflights, latitude and longitude of each waypoint were determined with LORAN/GNS instruments operated from an aircraft. Prior to an overflight, the observer at each study site sketched flock locations on the map. During an overflight, the observer in the aircraft announced the time at start, end, and each 0.16 km (0.1 mi) increment along the flight line via FM radio to the observer in the blind. Simultaneously, the observer on the ground described and recorded the response of the flocks on tape. This method enabled later reconstruction and mapping of aircraft position at the point along the flight path that corresponded to the exact time of flock response. Actual distance (aircraft to flock) as well as the lateral distance (perpendicular distance

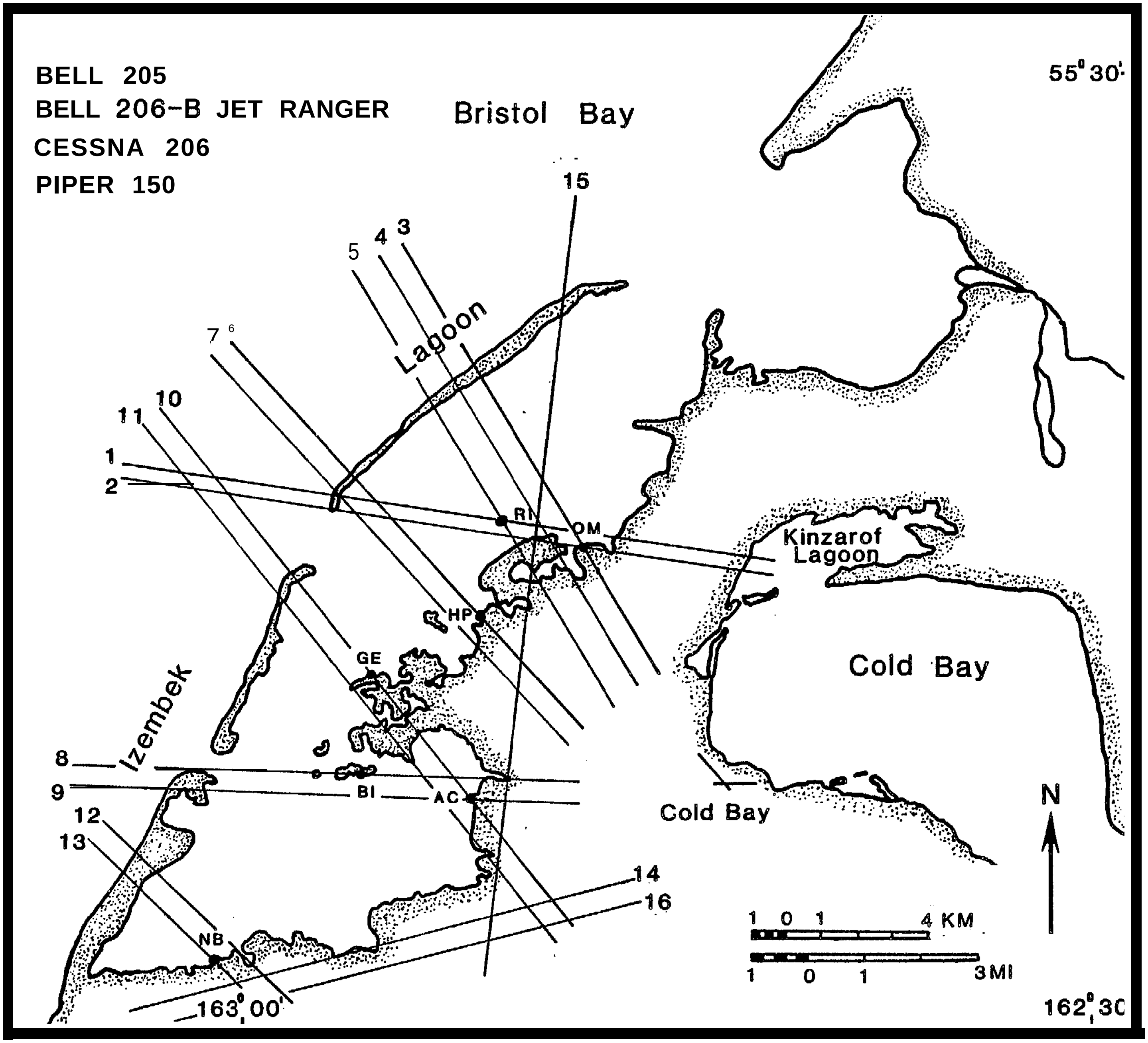


Figure 8. Numb er, position and orientation of experimental fixed-wing and helicopter overflights at Izembek Lagoon, Alaska between 23 September to 18 October 1987.

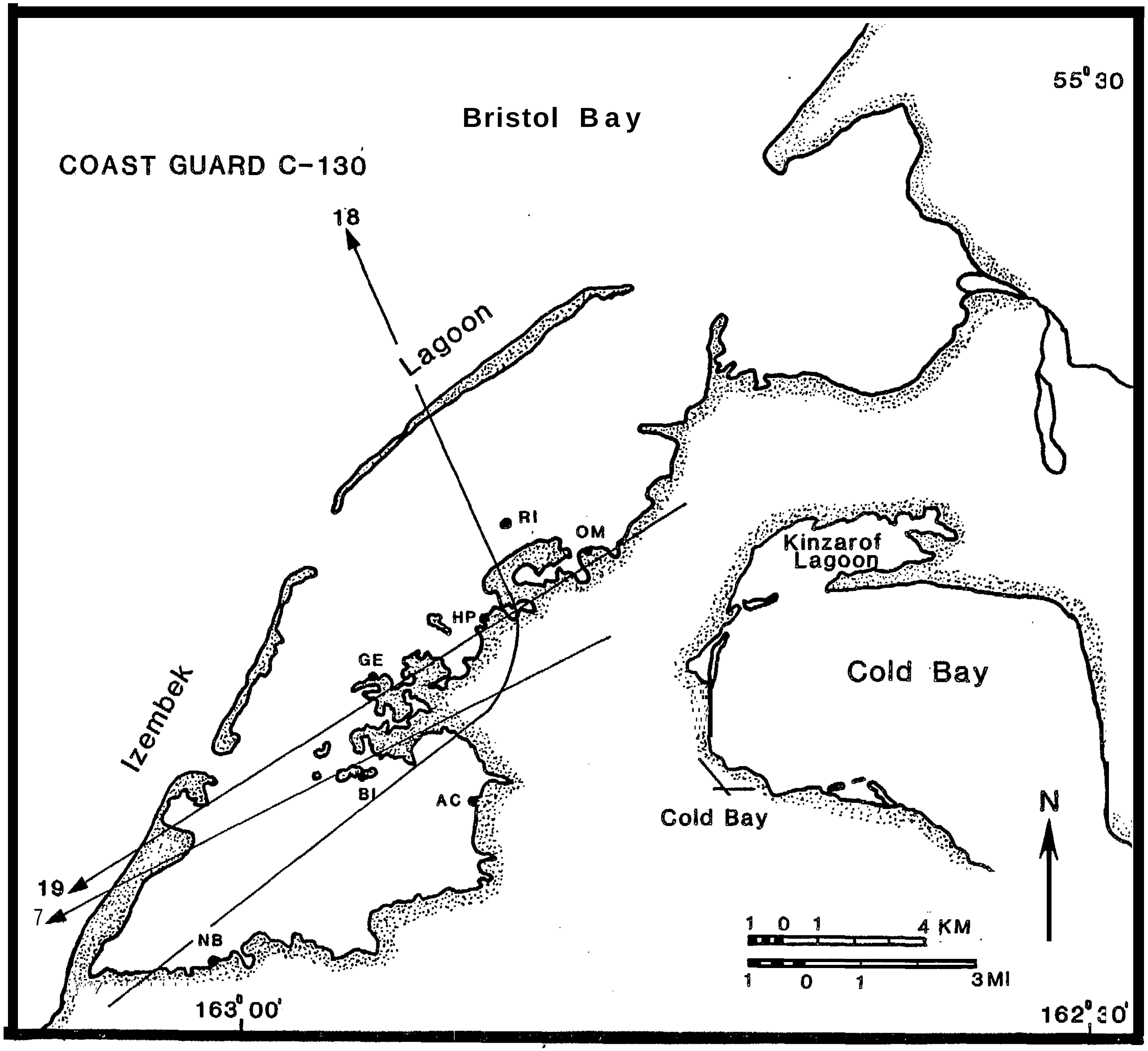


Figure 9. Number, position and orientation of experimental Hercules C-130 overflights at Izembek Lagoon, Alaska on 1 and 15 October, 1987.

Table 5. Summary of experimental aircraft overflights flown at Izembek Lagoon, Alaska, from 23 September to 18 October, 1987. See Figures 8 and 9 for locations of flight paths.

Aircraft type	Altitude (m)	No. of flight lines	No. flocks observed Brant	Canada	Emperor
Fixed-wing aircraft					
Piper-150/Cessna 206	76	1	1	0	0
	152	8	27	2	0
	305	15[a]	52	0	0
	Subtotals	24	80	2	0
Hercules C-130	305	3[b]	38	19	4
	Totals	27	118	21	4
Rotary-wing					
Bell 206-B	91	7	23	11	4
	152	10[c]	26	11	5
	305	8	17	7	1
	457	2	7	2	0
	Subtotals	27	73	31	10
Bell 205 .	91	19[d]	92	30	0
	152	30[a,e,f]	98	24	3
	305	25[f]	98	30	4
	457	12[e]	55	18	1
	610	14	53	22	0
	671	2[a]	5	4	0
	762	2	3	1	0
	914	4	9	3	0
	1,219	1	6	1	0
	Subtotals	109	419	133	8
	Totals	136	492	164	18
	Grand Totals	163	610	185	22

[a] One on flightline 14.
[b] All off regular flightlines.
[c] One off regular flightlines.
[d] Two on flightline 14.
[e] One on flightline 16.
[f] One on flightline 15.

from the flock to the aircraft flight line) were measured to the nearest 0.16 km (0.1 mi).

RESULTS AND DISCUSSION

Frequency of disturbance. A total of 1,967 potential disturbance (incidental and experimental) events were recorded in fall 1987 (Table 6). An event. is defined as an observation of a behavioral response, including no change in behavior, of a goose flock to a potential disturbance stimuli. A comparison of these events in 1987 with those of other years in the study, 1985 and 1986, showed the frequency of incidental disturbance was similar (Table 7).

The mean number of incidental disturbance events per hour of observation in 1987 (1.4/h) was similar to 1986 (1.3/h) and slightly less than in 1985 (1.6/h) (Table 7). Difference in the rate of incidental disturbance events between years is explained, for the most part, by relative changes in the frequency of aircraft traffic in and out of Cold Bay airport during the months of the study period (Table 8). Also , the length and time of day of observation periods, weather, and location of the study areas varied among years and influenced observed frequency of aircraft events.

In all years of the study, aircraft and hunter-related (gunshots or gunshots/person) events were the most frequent human-induced disturbances and eagles were the most important natural disturbance (Table 7). These disturbances were not uniformly distributed but concentrated within certain areas of Izembek Lagoon. Aircraft disturbances occurred primarily within the -Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) corridors (Figure lo). Large aircraft (jets, multi-engine and heavy twin-engine) primarily used the IFR and VFR 1 and 2 corridors while the smaller commuter airplanes (small twin- and single-engine airplanes) used VFR 3 corridor. Aircraft accounted for 54% of all incidental disturbances for all years and occurred with a frequency of 0.73 events per hour. Jets (13.7%), single-engine (12.8%), and multi-engine (10.0%) aircraft were the dominant types of aircraft disturbance for all years.

Approximately 40% of all aircraft traffic entering and leaving Cold Bay is comprised of commerical jets and the remaining portion is dominated by heavy and light twin-engine and single-engine airplanes (J. Yakal pers. comm.). Mean frequency of aircraft take-off and landings at Cold Bay airport per month in fall within the years of this study was 727 (SD = ± 202), which was slightly lower than the 12-year mean, 863 (SD = ± 237) (Table 8). In all years, the amount of aircraft traffic dropped in November compared to September and October.

For all years, hunting-related activities accounted for the majority (55%) of other human disturbances, but accounted for only 6% of all incidental disturbances. All other people-related activities (walking, fishing, clam-digging) or boating were even less frequent. Nearly all of these activities were confined to the central portion of the lagoon, primarily near GE/GW, HP, and RI/OM study areas. This area of the lagoon is the only portion that is easily accessible by road from Cold Bay. Because fewer hunters used Izembek Lagoon compared to prior years (C. Dau pers. comm.), the rate of hunting-related disturbances per hour in the 3 years of this study is relatively low (Figure 11).

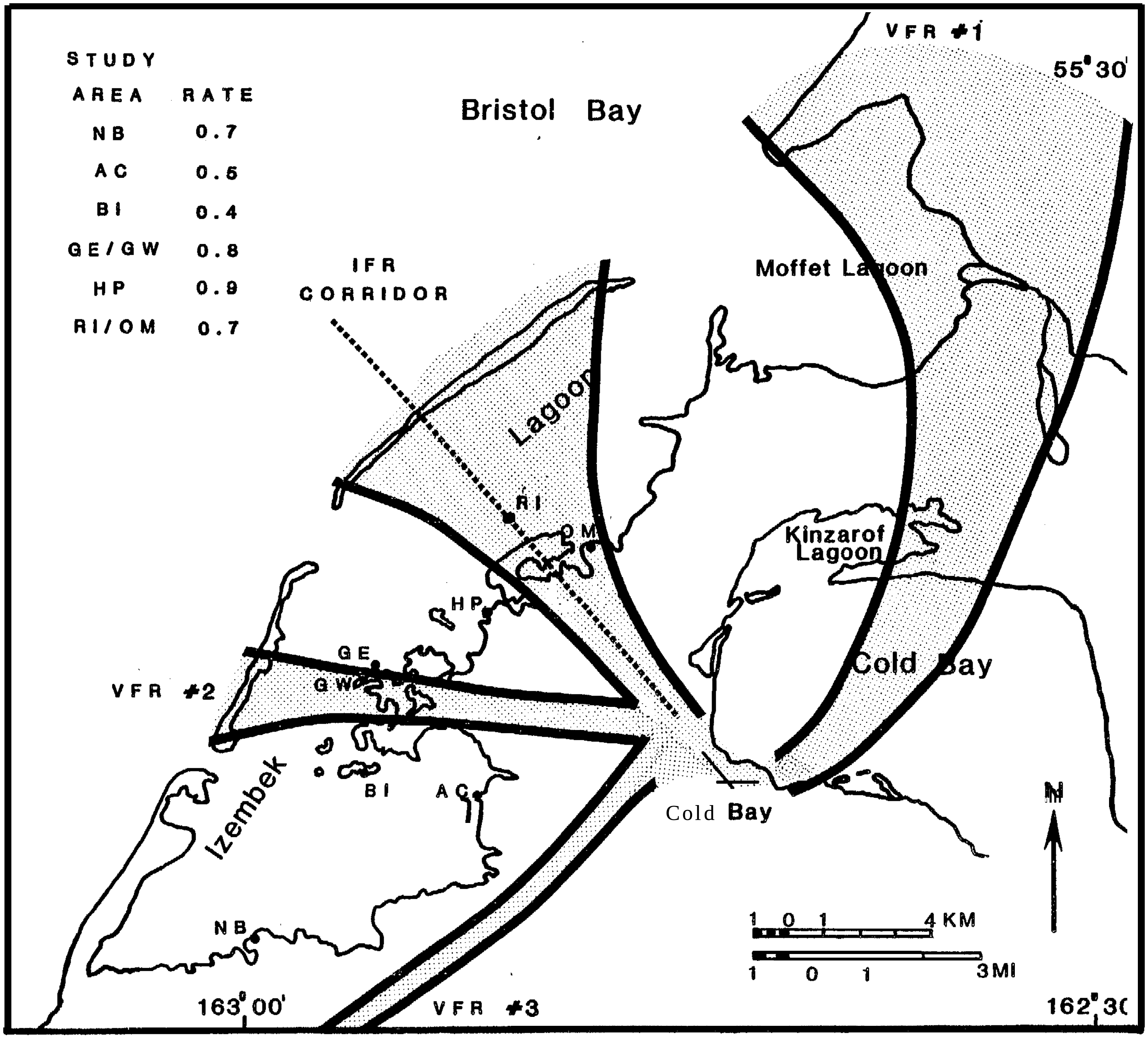


Figure 10. Distribution of incidental aircraft 'disturbances per hour of observation at each blind and locations of Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) corridors at Izembek Lagoon, Alaska 'during fall 1985-1987.

Table 6. Frequency of potential disturbance events for all geese at Izembek Lagoon from 1 September to 2 November 1987.

Study area	Total hrs in blind (%)	Days in blind	Mean h/d in blind	Mean number of disturbances per hour		Fixed-wing aircraft: As	AT	AH	AM	AJ[b]	A	Helicopter: HS	HK	Other Human: B	G[c]	P	Bird: E	F	O	Mammals: M	U	TOTALS
Grant Point (East)	106.4	21	5.1	1.6 (1.3)[a]	n	18	9	1	18	47	7	8	20	13	5	7	6	1	1	3	3	167
	(12.5)				%	6.9	11.1	16.7	11.5	25.5	8.9	7.0	3.6	48.1	35.7	14.9	2.0	2.5	2.8	37.5	5.5	8.5
Round Island	58.4	7	8.3	0.7 (0.7)	n	7	1	1	4	10	9	0	0	0	0	2	2	1	2	0	0	39
	(6.8)				%	2.7	1.2	16.7	2.6	5.4	11.4	0	0	0	0	4.3	0.7	2.5	5.6	0	0	2.0
Halfway Point	201.3	38	5.3	2.3 (1.3)	n	42	8	0	64	50	1	43	125	4	3	0	79	15	8	0	28	470
	(23.6)				%	16.0	9.9	0	41.0	27.2	1.3	37.7	22.2	14.8	21.4	0	26.7	37.5	22.2	0	50.9	23.9
Applegate Cove	152.9	22	6.9	2.7 (1.1)	n	28	19	0	25	22	19	33	184	2	4	2	55	3	7	2	6	411
	(17.9)				%	10.7	23.5	0	16.0	12.0	24.1	28.9	32.7	7.4	28.6	4.3	18.6	7.5	19.4	25.0	10.9	20.9
Banding Island	75.1	15	5.0	2.4 (0.7)	n	43	11	0	9	1	2	0	99	2	0	0	9	3	2	0	1	182
	(8.8)				%	16.4	13.6	0	5.8	0.5	2.5	0	17.6	7.4	0	0	3.0	7.5	5.6	0	1.8	9.3
Norma Bay	142.6	18	7.9	2.9 (0.7)	n	94	33	1	12	10	27	0	94	0	2	1	105	9	11	3	13	414
	(16.7)				%	35.9	40.7	16.7	7.7	5.4	34.2	0	16.7	0	14.3	2.1	35.5	22.5	30.6	37.5	23.6	21.1
Outer Marker	111.8	20	5.6	2.5 (1.8)	n	30	0	3	24	44	14	30	37	0	0	35	40	8	5	0	4	274
	(13.1)				%	11.5	0	50.0	15.4	23.9	17.7	26.3	6.6	0	0	74.5	13.5	20.0	13.9	0	7.3	13.9
Grant Point (West)	5.4	4	5.4	1.7 (1.1)	n	0	0	0	0	0	0	0	3	6	0	0	0	0	0	0	0	9
	(0.6)				%	0	0	0	0	0	0	0	0.5	22.2	0	0	0	0	0	0	0	0.5
TOTALS	853.9	48		2.3 (1.4)	n	262	81	6	156	184	79	114	562	27	14	47	296	40	36	8	55	1967
					%	13.3	4.1	0.3	7.9	9.4	4.0	5.8	28.6	1.4	0.7	2.4	15.0	2.0	1.8	0.4	2.8	

Fixed-wing aircraft: AH - Heavy twin-engine (e.g. YS-11); AJ - Jet (e.g. Boeing 727); AM - Heavy multi-engine (e.g. Lockheed C-L30, Electra); AS - Single-engine propeller (e.g. Arctic Tern); AT - Small twin-engine propeller (e.g. Piper Navajo); A - Unidentified aircraft.
Helicopter: HS - Small (e.g. Bell 206); HK - Large (e.g. Bell 205).
Other: B - Boats; P - Person; G - Gunshots.
Bird: E - Eagle; F - Falcon; O - northern harrier, rough-legged hawk, common raven, jaeger.
- 1 : M - brown bear, red fox, walrus, river otter.
U - Unidentified Cause.

[a] ( ) = mean number of potential disturbances per hour excluding experimental overflights.
[b] Includes 1 or more disturbances caused by small jet aircraft (e.g. Rockwell Sabreliner).
[c] Includes 2 combined gunshot and person disturbances.

Table 7. Frequency of potential incidental and experimental disturbance events for all geese at Izembek Lagoon, Alaska, fall, 1985-1987.

					HUMAN													NATURAL DISTURBANCES					
					Fixed-wing aircraft							Rotary-wing			Other			Bird			Mammal		
Year	Total hours of observations	Total days in blind	Mean number of disturbances per hour		AS	AT	AG	AH	AM	AJ	A	HS	HK	HL	B	G[b]	P	E	F	O	M	U	TOTALS
Incidental																							
19S7	853.7	4a	1.4 (2.3)[a]	n	1S6	81		6	95	184	79		-	-	27	47	14	296	40	36	8	55	11.54
				%	16.1	7.0		T	8.2	15.9	6.8		-	-	2.3	4.1	1.2	25.6	3.5	3.1	T	4.8	100.0
1986	79S.6	32	1.3 (2.5)[a]	n	115	88	21	67	52	?7	24			7	31	26	31	319	36	11	1	94	1030
				%	11.2	8.5	2.0	6.5	8.0	8.0	2.3			T	3.0	2.6	3.0	31.0	3.5	1.1	T	9.1	100.0
1965	259.5	23	1.6 (2.4)[a]	n	34	46	8	c	53	93	8			16	15	55	13	12	S	-	2		423
				%	8.0	10.9	1.9		19.6	20.0	1.9			3.8	3.5	20.1	3.1	2.8	1.9	-	T		100.0
			Totals	n	335	215	29	73	260	354	111			23	73	15s	58	62?	S4	47	11	149	2607
				%	12.8	8.2	1.1	2.s	10.0	13.7	4.3			T	2.8	6.1	2.2	24.1	3.2	1.8	T	5.7	100.0
Experimental																							
1987				n	76				61			114	562	-	-		-	-	-	-			813
				%	9.4				7.5			14.0	69.1	-	-		-	-	-	-			100.0
1986				n	22s	209	58		37			404		61	-		-	-	-	-			997
				%	22.9	21.0	5.8		3.7			40.5		6.1	-		-	-	-	-			100.0
1985				n	131							69	-	-	-		-	-	-	-			200
				%	65.5	-	-	-	-	-	-	34.5	-	-	-	-	-	-	-	-			100.0
			Totals	n	435	209	58	-	98	-	-	5s7	562	61	-	-	-	-	-	-			2010
				%	21.6	10.4	2.9	-	4.9	-	-	29.2	2S.0	3.0	-	-	-	-	-	-			100.0

Fixed-wing aircraft: AS - Single-engine propeller (e.g. Piper 150, Cessna 206, Cherokee Chief); AT - Twin-engine propeller (e.g. de Havilland Twin Otter, Piper Navajo); AG - Grumman Goose; AS - Heavy twin-engine propeller (e.g. NAMC YS-11, Douglas DC3); AM - Heavy multi-engine propeller - (e.g. Lockheed C-130 Hercules, Electra L188); A.7 - Jet (e.g. Boeing 727-200, Gulfstream II); A - Unidentified aircraft.
Helicopter: ES - Small (e.g. Bell 206-B); HK- Large (e.g. Bell 205); HL - Larger (e.g. Sikorsky HH-3F).
Other: B - Boats; G - Gunshots; P - Person.
Bird: E - Eagle (e.g. bald eagle); F - Falcon (e.g. gryfalcon, peregrine falcon); O - Other birds (e.g. rough-legged hawk, northern harrier, common raven).
mammal : M - Mammals (e.g. wolf. red fox, river otter, brown bear); T - indicates <1.0%.
U - Unidentified cause.

[a] ( ) = mean number of potential dis turbances per hour including experimental overflights
[b] Includes eight combined gunshot and person dis turbances.
[c] Twin-engine aircraft include heavy twin-engine airplanes.

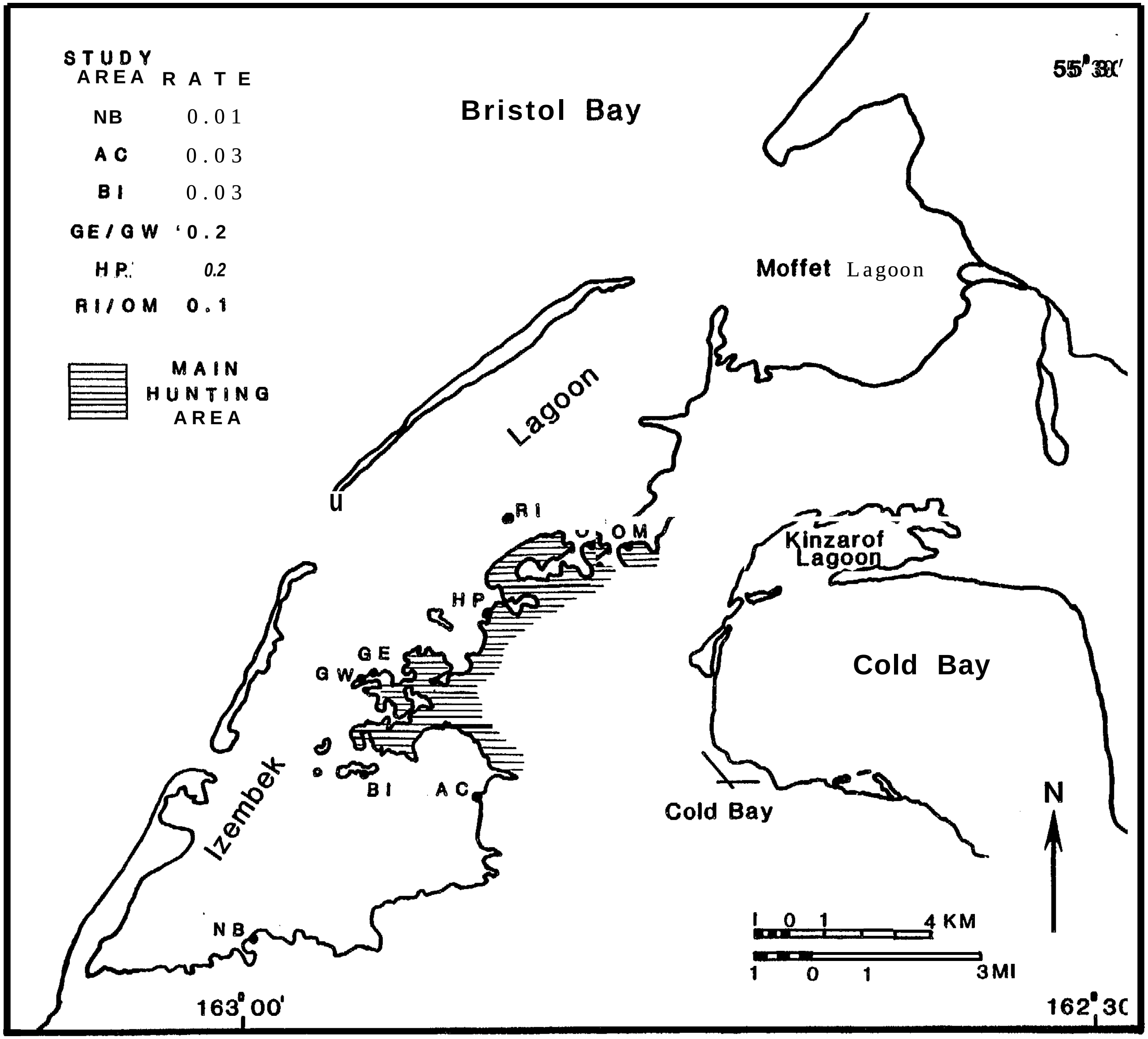


Figure 11. Distribution of incidental hunting-related disturbances per hour of observation at each blind at Izembek Lagoon, Alaska during fall 1985-1987,

Table 8. Frequency of aircraft use (landings and take-offs) of Cold Bay airport, Cold Bay, Alaska, during fall 1985-87 and the 12 year mean (1976-1987)(SD and range). Source of data taken from Federal Aviation Administration records (J. Yakal pers. comm.)

Month	1985	1986	1987	1976-1987
September	834	693	843	970 (±194; 746-1294)
October	964	781	977	997 (±156; 762 -1309)
November	484	482	485	620 (±141; 457-849)
All months	760 (±248)	652 (±154)	768 (±254)	863 (±237; 457-1309)

Brant were disturbed by many natural causes, but by far the most important was bald eagles (82% of all known natural disturbances). Eagle disturbances were frequent and occurred at all study areas. The highest rate of disturbances per hour was in areas containing the greatest number of geese (NB, AC and HP study areas) (Table 9). Eagles were not present during the beginning of the fall study period but arrived in early October and were still present in November.

Comparisen of response to various types of aircraft. Both experimental and incidental data from all years, study areas, and observers were combined for this analysis. Multiple regression was used to determine a single quadratic equation for each aircraft type that best predicted the percent of flocks showing flight response (rise, circle, or depart) based on altitude, lateral distance, and altitude and lateral distance squared. These equations were:

Single-engine:

$$\%\ \text{flight} = 65.5 - 63.14\ A + 1.93\ AA - 18.65\ L + 1.83\ LL$$

Multi-engine:

$$\%\text{-flight} = 96.4 - 20.26\ A + 15.83\ AA - 57.22\ L + 11.93\ LL$$

Bell 206-B :

$$\%\ \text{flight} = 68.2 - 17.20\ A + 2.52AA - 61.65\ L + 13.04\ LL$$

Bell 205:

$$\%\ \text{flight} = 90.7 + 16.89\ A - 3.36\ AA - 85.31\ L + 14.96\ LL$$

A = altitude in increments of 1,000 ft
AA = (altitude in increments of 1,000 ft)^2
L = lateral distance in mi
LL = (lateral distance in mi)^2

The equations were solved for a series of response levels (brant flocks exhibiting 0, 20, 40, 50, and 80% response to a disturbance) to assess the interactive influence of lateral distance and altitude on flight response (Figures 12 and 13). Response to single-engine and multi-engine airplanes was decreased by both greater altitude and greater lateral distance. Response to helicopters was decreased with greater lateral distance, but percent response was either slightly influenced (Bell 206-B) or increased (Bell 205) at greater altitude.

This regression approach was also repeated to consider a second dependent variable, the percent of brant showing alert, mass, or flight responses. The regression model also was expanded to evaluate the relative importance of 6 categorical factors: experimental versus incidental overflights, social facilitation (present or absent), wind direction (upwind or downwind), direction of travel (towards or lateral), flock size ($\leq$500 or > 500), and distance from shore ($\leq$0.4 km vs. >0.4 km). These 6 dummy variables were assigned values of +1, 0, or -1.

Multiple R-squared values for regression on flight response ranged from 0.36 to 0.59 for helicopters, and 0.11 to 0.51 for fixed-wing aircraft (Table 10). Behavioral response by brant to twin-engine or jet aircraft stimuli was poorly predicted by the regression model (Table 10). The model was able to determine the influence of certain factors on the behavioral response by brant to

Table 9. Mean number of aircraft, hunter-related (gunshots, person and gunshot/person), eagle, and total incidental disturbances per hour of observations at each study area of Izembek Lagoon, Alaska, fall 1985-1987.

	Disturbances per hour			
Study area	Aircraft	Hunter-related	Eagles	Total
AC	0.5	0.03	0*5	1.1
BI	0.4	0.03	0.2	0.9
GE/GW	0.8	0.20	0.1	1.3
HP	0.9	0.20	0.3	1.7
NB	0.7	0.01	0.8	1.9
RI/OM	0.7	0.10	0.2	1.3

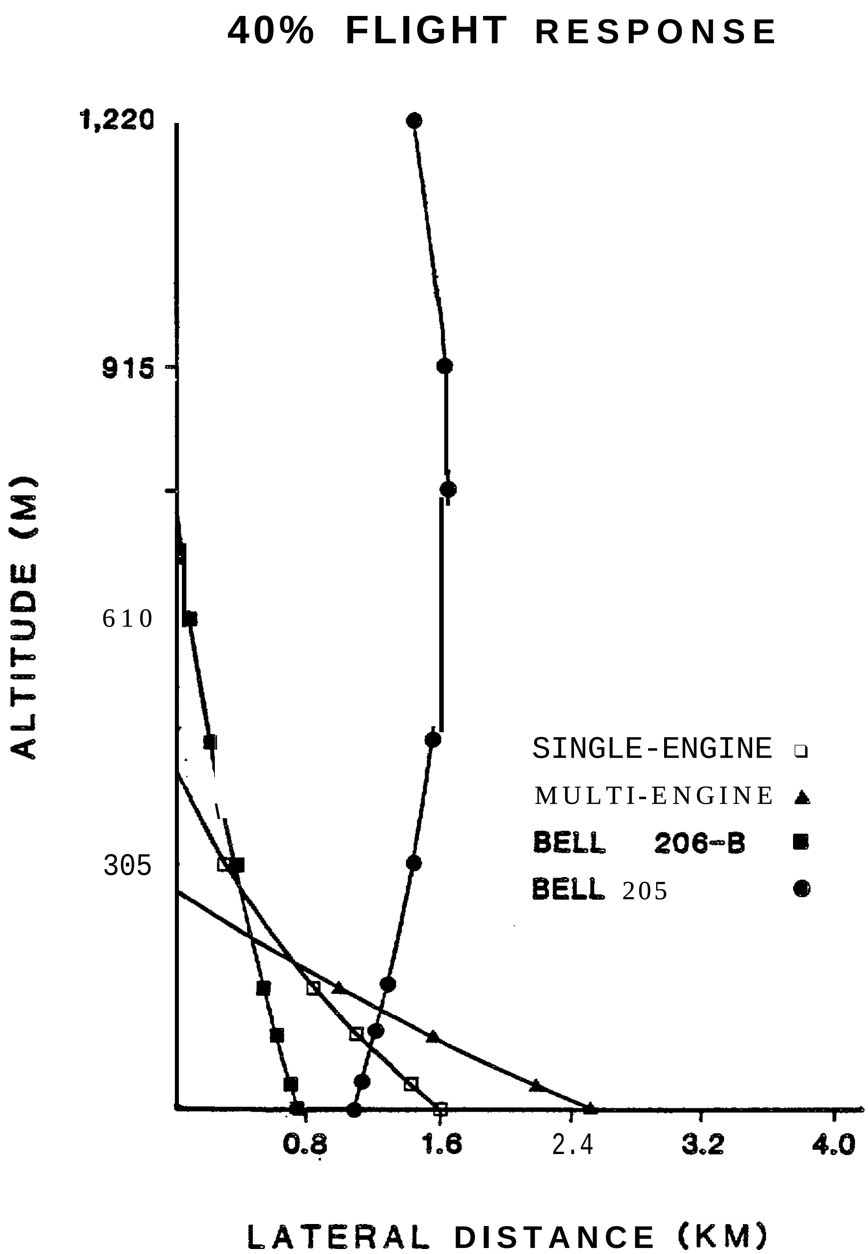


Figure 12. Flocks of brant exhibiting a 40% flight response to changes in altitude and lateral distance of 4 types of aircraft at Izembek Lagoon, Alaska, fall 1985-1987.

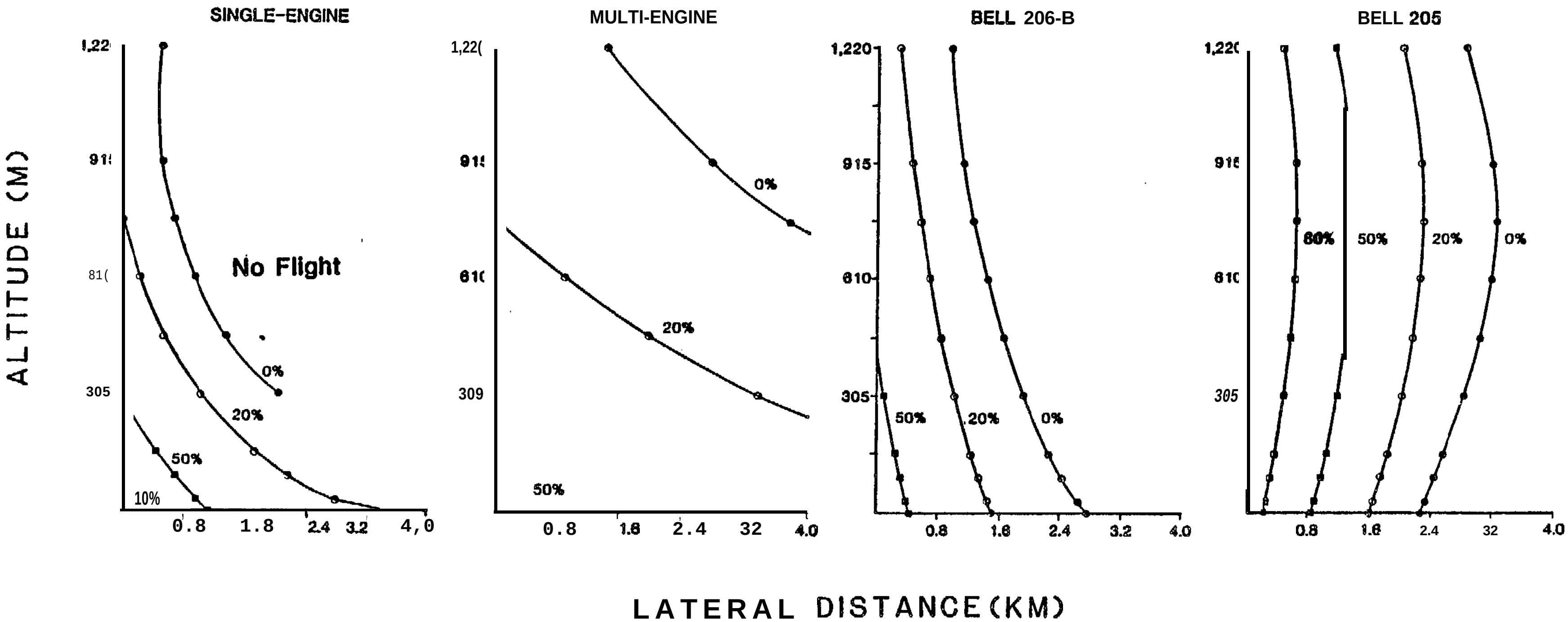


Figure 13. Flocks of brant exhibiting 0, 20, 50, 80% flight response to changes in altitude and lateral distance of 4 types of aircraft at Izembek Lagoon, Alaska, fall 1985-87.

Table 10. Probability level of significant coefficients in multiple regression model for percent response and percent flight response of brant flocks to aircraft overflights at Izembek Lagoon, Alaska, fall, 1985-1987.

Response categories	Single-engine	Twin-engine	Multi-engine	Jet	Bell 206-B	Bell 205
	Aircraft type					
n	413	147	160	120	257	420
Percent response						
R-square =	.53	.24	.46	.23	.45	.61
altitude	.000		.011			.000
$(altitude)^2$	.000		.071			.001
lateral distance	.000	.000	.000	.000	.000	.000
$(lateral\ distance)^2$	,000	.004	.003	.007	.000	.000
experimental/incidental	.007					.017
social facilatation	.017		.000			.000
wind direction			.071		.009	.005
direction of travel	.000	.038	.000		.001	
flock size					.038	
distance from shore	.002					
Percent flight response						
R-square =	.51	.11	*41	.16	.36	.59
altitude	.000		.018			.004
$(altitude)^2$	.000					.036
lateral distance	.000	* 014	.052	.003	.000	.000
$(lateral\ distance)^2$	.000	.042		.033	.000	.000
experimental/incidental	.005		.003			.020
social facilitation			.004		.019	.000
wind direction					.002	.012
direction of travel	.001		.000		.006	
flock size						.044
distance from shore	.026					.028

Table 11. Mean, 10%, and 90% quantile ranges for behavioral responses of brant flocks and conditions associated with aircraft overflights at Izembek Lagoon.

Aircraft type	n	Mean	10%	90%
Single engine: Piper 150/ Cessna 180, 185, 206				
% response	568	50	0	100
% flight response	568	34	0	100
altitude (m)	560	299	61	610
lateral distance (km)	419	1.3	0	3.5
actual distance (km)	452	1.4	0	3.5
Twin-engine: Piper Navaho				
% response	275	33	0	100
% flight response	275	14	0	100
altitude (m)	258	372	152	777
lateral distance (km)	154	2.6	0	6.4
actual distance (km)	226	2.1	0.2	4.8
Four-engine: Hercules C-130				
% response	250	29	0	100
% flight response	250	18	0	100
altitude (m)	214	860	152	2,134
lateral distance (km)	175	3.5	0	9.6
actual distance (km)	161	3.5	0.2	8.7
Jet: Boeing 727				
% response	225	27	0	100
% flight response	225	16	0	100
altitude (m)	161	1,472	366	2,743
lateral distance (km)	144	4.2	0.3	8.0
actual distance (km)	145	4.0	0.6	8.7
Small helicopter: Bell 206-B				
% response	420	54	0	100
% flight response	420	36	0	100
altitude (m)	420	344	91	914
lateral distance (km)	258	1.3	0	3.2
actual distance (km)	324	1.4	0	3.2
Large Helicopter: Bell 205				
% response	421	74	0	100
% flight response	421	61	0	100
altitude (m)	421	315	91	610
lateral distance (km)	421	1.0	0	2.4
actual distance (km)	219	3.2	1.6	5.5

different aircrafts. The number of brant in a flock or the flock's distance from shore had little effect on behavioral response. Wind direction (upwind vs. downwind) in relationship to the location of the aircraft at the time it first influenced a flock was more important for helicopters than for fixed-wing aircraft. A helicopter upwind from a flock had a greater influence than a helicopter downwind at similar lateral distances to the flock. Wind direction had little effect on fixed-wing aircraft, only having an influence with multi-engine airplanes. The direction an aircraft was traveling, either directly towards or lateral to a flock, was important for fixed-wing aircraft. Airplanes that flew directly towards (≤4 km away) flocks had more influence on the behavioral response by brant than airplanes lateral to flocks (>0.4 km away). Social facilitation, that is the effect of predisturbed flocks joining an observed flock and potentially influencing their response, had mixed results for the different aircraft and needs further analysis. Other parameters that have not yet been quantified are effects of tide height, tide flow, study area, time of day, year, date and observer.

Behavioral response by brant flocks caused by various types of aircraft are legitimately compared only under the same range of conditions of altitude, lateral distance, and other factors. Comparison of response among aircraft at a given altitude, lateral distance, or response level should not be extrapolated beyond the range of the data on which the regression relationship was based. Sample size, mean, and 10 and 90% quantile points that identify the range of the central 80% of the distribution (Table 11) indicate the difficulty, for instance, of directly comparing responses to jet aircraft and single-engine aircraft. The low level of response to twin-engine aircraft, combined with lack of lateral distance measures for the cases in which response occurred, caused this particular regression approach to not be very relevant. Other measures to compare twin-engine and jet aircraft with the other types will be investigated.

ACOUSTICS OF AIRCRAFT OVERFLIGHTS

INTRODUCTION

A primary concern of frequent aircraft overflights at Izembek Lagoon is the potential disruption of foraging caused by increased alarm and escape response of geese. Frequent disruption could result in decreased energy storage and increased mortality during migration and non-breeding. During the previous 2 years of this study we tested several aircraft at various altitudes, and lateral distances to study flocks. However, the noise component of these overflights was not measured, nor has noise level been related to the behavioral response of the geese. In fall of 1987 we initiated additional research to measure aircraft noise at Izembek Lagoon to provide a more complete understanding of the behavior of brant and other geese to aircraft overflights.

The objectives are to: 1) relate behavioral responses of geese to noise from aircraft overflights, and 2) record and analyze noise levels associated with experimental and incidental overflights.

METHODS

Study area. All noise levels were measured at Grant Point (Figure 14). This site was selected because its location near the tip of a peninsula minimized possible differences of recording noise over land and at the water surface where geese occurred. The Grant Point site was close to the GE study area, located under established flight lines for experimental aircraft overflights, and convienent for set-up of the monitoring equipment. The microphone was placed 2 m (6 ft) above ground level and 17 m (55 ft) above mean sea level.

Aircraft overflights. Forty-two noise recordings were made of 5 types of aircraft on 6 days between 5 October and 1 November. Noise level was measured on 3 types of fixed-wing aircraft (Piper 150, Cessna 180 and 206) and 2 types of rotary-wing aircraft (Bell 206-B Jet Ranger and Bell 205). The Bell 205 was selected because of its similarity to the larger helicopters (e.g. Bell 212, Bell 412) typically used by the petroleum industry for Outer Continental Shelf exploration.

Techniques for the overflights used for noise measurements were the same as the experimental overflights described in the aircraft disturbance section. All passbys were level flight along 4 lines, 0.8 km (0.5 mi) apart (Figure 14). The air speed of the aircraft during passbys remained constant near 161 kmh (100 mph). The altitude and lateral distance to the microphone of the overflights varied for each aircraft, but most overflights were made at 3 altitudes, 152, 305, and 610 m (500, 1000 and 2000 ft), respectively, and 3 lateral distances to the microphone, 0.0, 0.8, and 1.6 km (0.0, 0.5, and 1.0 mi), respectively.

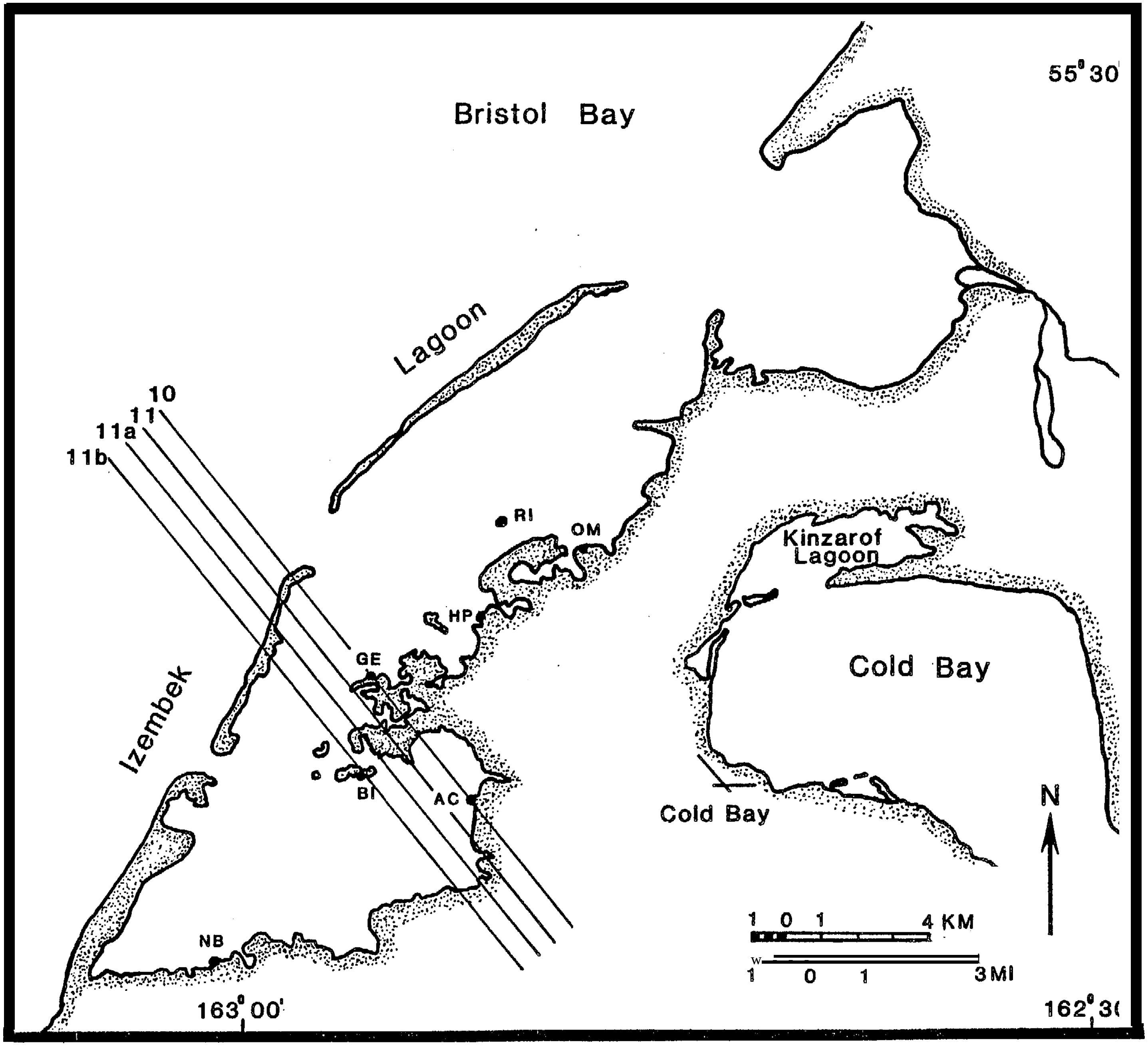


Figure 14. Number, position and orientation of experimental fixed-wing and helicopter acoustic overflights at Izembek Lagoon, Alaska, between 5 October and 1 November 1987.

Noise measurements. Noise levels were received through a Bruel and Kjaer outdoor microphone (type 4921) and analyzed and stored on a Larson-Davis 3100 real time spectrum analyzer (RTA). The RTA was programmed to measure 1/3 octave bands, and overall A-, C-, and un-weighted levels every 1/2 second over a frequency range of 10 Hz-10 KHz for 2:30 min. Technical specifications of the microphone and RTA are presented in Appendices A and B, respectively. The total integrated SEL and L_{max} were measured and stored by the RTA during each overflight. To insure that noise measurements of aircraft were not influenced by ambient or background environmental noise, background noise was measured and entered into the RTA prior to an overflight. This procedure ensures that the recorded noise level is that of the aircraft. Because the audibly detectable duration of an overflight from start to end exceeded the 2:30 min memory of the RTA, the start for recording of a passby was delayed so that only the loudest 2:30 min period was analyzed. This included the time when the aircraft was closest, and directly overhead or perpendicular to the microphone.

Selecting a particular standard frequency weighting scale with which to measure aircraft noise was difficult because of the lack of information on the audible frequency range of brant. In general the audible frequency range of birds (40 Hz - 21kHz) is similar to human's (20Hz - 16 kHz) although birds are less sensitive to higher and lower tones within their hearing range (Schwartzkopff 1973). The audible frequency range of brant may be comparable to the range of 3 Hz - 8 kHz measured for mallards (*Anas platyrhynchos*) with a maximum sensitivity range of 2 - 3 kHz (see Schwartzkopff 1973).

We measured noise intensity with both the A- and C-weighted scales. A-weighted scale is the measure commonly used for assessing environmental noise with respect to human disturbance. It is derived from the inverse of the hearing acuity of the human ear to low sound levels. The A-weighted scale assigns lower weights to lower frequency tones, to which the human is less sensitive, and higher weights to higher frequency tones which are more disturbing. The C-weighted (flat) scale does not weight the signal, but enables the sound energy to be measured with no modification. ,

Behavioral response of brant. Categories of behavioral response of brant were the same as those used in the disturbance section. The average noise measurements of the aircraft were compared with average behavioral response of brant to these same aircraft for the same combinations of lateral distance and altitude. The behavior data were combined from all flocks over any date, time, or location in the lagoon.

RESULTS AND DISCUSSION

Noise measuerements of aircraft. Although sample sizes are small, three aspects of aircraft noise are immediately apparent. First, measured noise levels varied for each type of aircraft with the Bell 205 helicopter producing the greatest amount of noise. The Bell 205 generated a SEL of 95 dBA during overflights of 152 m and within $\leq$ 0.3 km ($\leq$ 0.2 mi) lateral distance to the microphone (Table 12). The smaller Bell 206-B helicopter was considerably quieter (SEL of 83.4 dBA) than the Bell 205 and was comparable to the larger single-engine airplanes, Cessna 180 (SEL of 83.4 dBA) and 206 (SEL of 85.0 dBA). The Piper 150 was the quietest aircraft tested (SEL of 76.4 dBA).

Table 12. The mean integrated sound exposure level (SEL) and maximum sound level (L_{max}) of five types of aircraft at 152 m (500 ft) altitude and <0.3 km (<0.2 mi) lateral distance at Izembek Lagoon, Alaska, fall 1987.

Aircraft type	n		SEL (dBA)	L_{max} (dBA)
Single-engine				
Piper 150	2		76.4	70.1
		range	(75.1-77.7)	(68.4-71.7)
Cessna 180	2		83.4	78.2
		range	(83.3-83.6)	(77.5-78.8)
Cessna 206	2		85.0	76.6
		range	(84.7-85.1)	(75.9-77.2)
Combined	6		81.6	74.9
		range	(75.1-85.1)	(68.4-77.2)
Helicopter				
Bell 206-B	1		83.4	74.9
Bell 205	3		95.0	84.4
		range	(94.0-96.1)	(83.6-85.7)

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Converting from the logarithmic dB scale, the large Bell 205 helicopter was approximately twice as loud as the smaller Bell 206-B and 4 times as loud as the Piper 150.

One reason for the large difference in noise levels of the Bell 205 and piston-powered, single-engine aircraft is the additional noise component of helicopters produced by the interaction between vortices and successive sweeps of the rotor blades (Newman et al. 1984). Although this component was audible in the Bell 206-B, it was especially apparent in the Bell 205.

The sound intensity was attenuated with either increased altitude or greater lateral distance of the aircraft to the microphone (Table 13). As altitude was increased from 152 to 305 to 610 m, respectively, the L_{max} of the Cessna 206 decreased from 76.6 to 64.0 dBA and for the Bell 205 from 84.4 to 77.9 dBA (Table 13). Similarly, when lateral distance was increased to 1.6 km at 152 m altitude, the L_{max} of both aircraft decreased from 76.6 to <47.3 dBA for the Cessna 206 and 84.4 to 65.4 dBA for the Bell 205. This-relationship was recorded to some degree for all aircraft, but because of sample size was best represented for the Cessna 206 and Bell 205.

Propagation of noise is influenced by spherical spreading with distance, atmospheric absorption as affected by wind, temperature, air pressure, and relative humidity, and intervening barriers such as foliage and ground cover (Harrison et al. 1980). Spherical spreading is the loss of acoustic energy as sound waves spread over a larger and larger area. Typically, loudness (amplitude) of a sound decreases as the distance between the sound source and the receiver increases. For subsonic noise, doubling the relative distance causes a decrease or loss in acoustic intensity (loudness) of approximately 6 decibels.

The combination of increased altitude at greater lateral distance to the microphone had a different effect; the amount of attenuation decreased. Noise levels remained the same or slightly increased above those of the lower altitudes (Table 13). At 0.8 km lateral distance, L_{max} for the Bell 205 at 152 and 610 m decreased from 73.5 to 72.0 dBA. At 1.6 km, for the same increase in altitude, L_{max} increased from 65.4 to 72.0 dBA. At greater lateral distances, the sound level from the Bell 205 helicopter increased with increased altitude rather than the expected decrease. Reasons for this are complex because noise levels are influenced by many factors including characteristics of the aircraft. The phenomena was evident with both the Cessna 206 and Bell 205, but was observed over a wider range of altitudes and lateral distances with the Bell 205. The wider range of influence of the Bell 205 was probably indicative of its' greater noise levels, particularly in the low frequency range (P. Schemer pers. comm.), and the lack of noise intensity of the Cessna 206 that is distinquished above background levels. Low frequency sound levels travel further than high frequency sound levels.

Behavioral response of brant. The average flight response of brant was highly correlated (R^2 = 0.80) with noise level for each of the various combinations of aircraft type, lateral distance, and altitude (Figure 15).

The initiation (distance of response) and magnitude of the behavioral response of brant corresponded with the intensity of noise generated by the Bell 205. The response of brant increased as altitude of the Bell 205 helicopter was increased. For example, at 0.8 km (0.5 mi) lateral distance (Table 14) the

Table 13. The mean maximum sound (L_{max}) and integrated sound energy level (SEL) and percent attenuation (Att) from maximum levels of a Cessna 206 airplane and Bell 205 helicopter at Izembek Lagoon, Alaska, fall 1987.

Altitude (m)	Lateral Distance (km)	Cessna 206 n	Cessna 206 L_{max} (dBA)	Cessna 206 Att (%)	Cessna 206 SEL (dBA)	Cessna 206 Att (%)	Bell 205 n	Bell 205 L_{max} (dBA)	Bell 205 Att (%)	Bell 205 SEL (dBA)	Bell 205 Att (%)
610	≤0.3	2	64.0	84%	76.3	90%	1	77.9	92%	91.3	96%
305	0.0	2	72.1	94%	83.0	98%	2	78.2	93%	92.7	98%
152	0.0	2	76[illegible]	100%	85.0	100%	3	84.4	100%	95.0	100%
152	0.8	1	59.8	78%	69.3	82%	4	73.5	87%	84.0	88%
305	0.8	1	61.9	81%	70.1	82%	2	70.7	84%	82.8	87%
610	0.8	1	a		a		1	72.0	85%	80.5	85%
152	1.6	1	a		a		1	65.4	77%	74.6	79%
305	1.6	1	a		a		1	68.8	81%	77.9	81%
610	1.6	1	a		a		1	72.0	85%	84.8	89%

a Measurements could not be distinguished from background noise (L_{max} of 47.3 dBA and SEL of 69.1 dBA).

Table 14. Mean Integrated sound exposure level (SEL) maximum sound level (L_{max}) and response of brant flocks to a Bell 205 helicopter at various altitudes and lateral distances at Izembek Lagoon, Alaska, fall 1987.

Altitude (m)[a]	Lateral distance (km)[b]	n	SEL (dBA)	L_{max} (dBA)	n	Distance of first response (km)	n	Distance of flight response (km)	n	Flight (%)[c]	n	Duration of response
152	0.3	3	95.0	84.4	29	2.7	50	1.8	62	98	46	201
305	0.3	2	92.7	78.2	11	3.4	18	2.1	22	100	15	272
610	0.3	1	91.3	77.9	14	3.7	19	2.9	23	87	16	273
152	0.8	4	84.0	73.5	22	2.7	18	1.3	35	54	21	174
305	0.8	2	82.8	70.7	15	3.2	20	1.9	29	72	23	160
610	0.8	1	80.5	72.0	5	4.8	10	3.1	11	80	11	198
152	1.6	1	74.6	65.4	19	2.9	5	1.3	34	6	31	92
305	1.6	1	77.9.	68.8”	9	3.2	5	0.5	15	60	11	282
610	1.6	1	84.8	72.0	7	2.9	7	2.4	13	77	8	191

[a] Altitudes of: 152 m includes > 76 and $\leq$229 m.
305 m includes >229 and $\leq$381 m.
610 m includes >381 and $\leq$685 m.

b Lateral distances of: 0.3 km includes $\leq$0.3 km.
0.8 km includes $>$0.3 $\leq$ 1.0 km.
1.6 km includes >1.3 $\leq$1.6 km.

[c] Flocks exhibiting >50% flight response.

Table 15. Comparison of mean integrated sound exposure level (SEL), maximum sound level (L_{max}) and response of brant flocks to single engine airplanes[a] Bell 206-B, and a Bell 205 helicopters at 152 m (500 ft) and 305 m (1000 ft) and ≤0.3 km (≤0.2 mi) lateral distance at Izembek Lagoon, Alaska, fall 1987.

Aircraft type	n	SEL (dBA)	L_{max} (dBA)	n	Distance of first response (km)	n	Distance of flight response (km)	n	50% flight (%)[b]	n	Duration of response (s)
152 m											
Single-engine	6	81.6[c]	74.9[c]	3	1.4	14	1.0	63	76	33	143
Bell 206-B	1	83.4	81.5	14	1.8	10	0.6	68	78	25	133
Bell 205	3	95.0	84.4	29	2.7	50	1.8	62	98	46	201
305 m											
Single-engine	4	77.7[c]	69.6[c]	9	1.0	13	1.0	61	36	26	94
Bell 206-B	1	81.4	69.3	3	1.6	1	1.0	105	47	32	107
Bell 205	2	92.7	78.2	11	3.4	18	2.1	22	100	15	272

[a] Includes Arctic Tern, Piper 150, and Cessna's 180, 185 and 206.
[b] Flocks exhibiting ≤50% flight response.
[c] Includes Piper 150, Cessna 180, and Cessna 206.

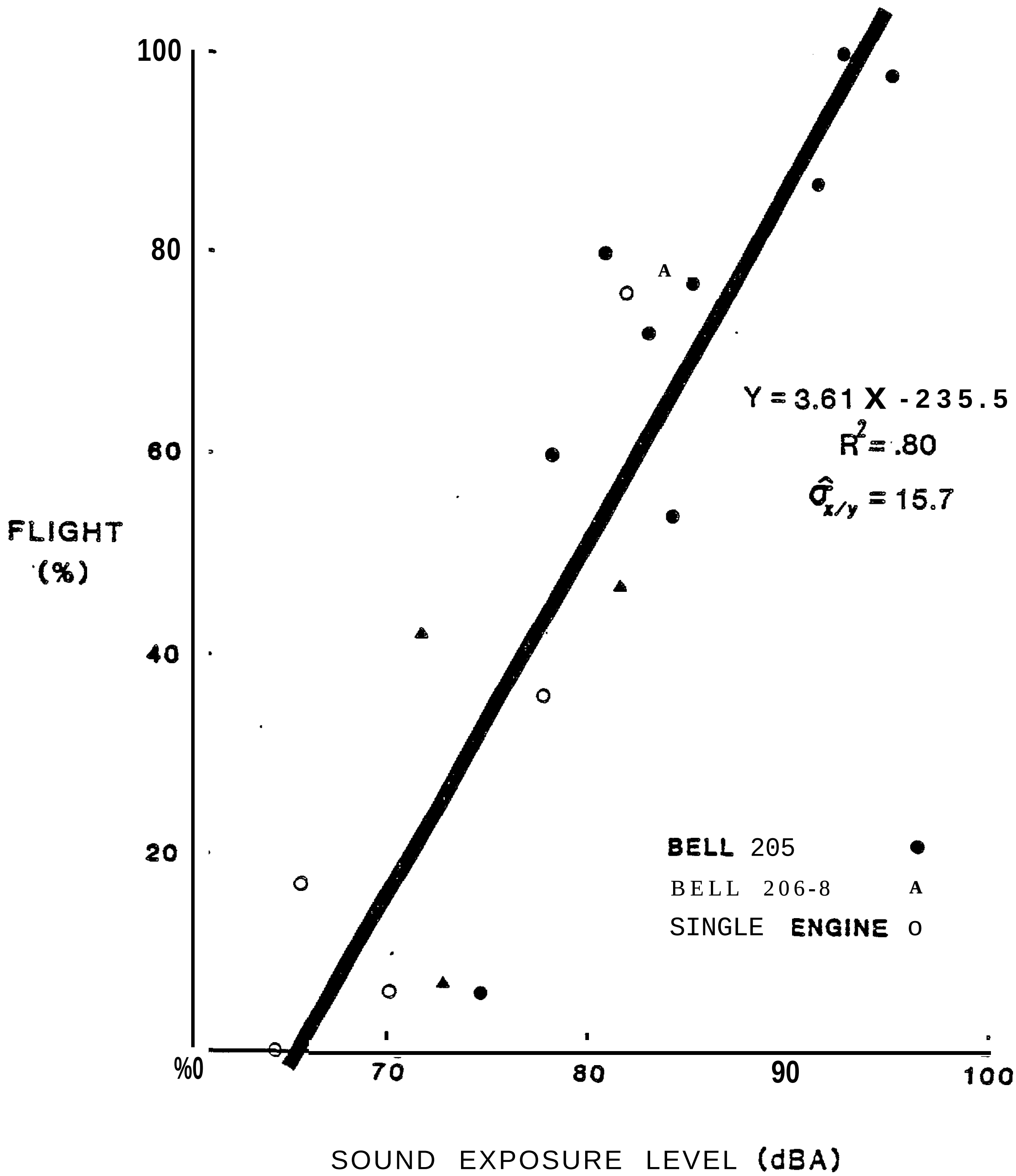

Figure 15. Flocks of brant exhibiting ≥ 50% flight response to noise generated by single-engine airplanes and Bell 206-B and Bell 205 helicopters at Izembek Lagoon, Alaska, fall 1987.

percent of brant flocks exhibiting at least 50% flight increased from 54% to 80% as altitude was increased from 152 to 610 m. At 1.6 km lateral distance, the flight response of brant increased from 6% to 77% as altitude increased from 152 to 610 m. This suggests that the Bell 205 causes greater disturbance (i.e. wider area of influence) at increased altitudes. This pattern is different from that shown by brant in response to single-engine airplanes and the Bell 206-B helicopter (Table 15). The percent of flocks that showed at least 50% flight decreased with increased altitude.

Aircraft produce both visual and auditory stimuli. Our data indicates that brant response is correlated to the strength of an auditory stimulus. However, it is not known whether the response of brant is solely auditory or a combination of both auditory and visual.

Although not directly measured, the threshold noise level for flight of brant appears to occur at or above a SEL of 65 dBA (Figure 15) or a L_{max} of 60 dBA (Table 14). Although the frequency/response correlation or threshold of response of geese or other birds during staging or non-breeding are lacking, aircraft disturbance studies have shown much higher threshold noise levels for nesting birds than for brant. Black et al. (1984) found that great egrets (Casmerodius albus), snowy egrets (Egretta thula), and cattle egrets (Bulbulcus ibis) initiated alert movements when noise generated from F-16 overflights reached 60-65 dBA; birds began changing their position at 70-75 dBA. Black-crowned night herons (Nycticorax nycticorax) and great egrets were not disturbed by Cessna 172 overflights (altitude: 46-244 m) which increased from 61 to a maximum of 88 dBA (Grubb 1978). Burger (1981) observed herring gulls (Larus argentatus) flying after a supersonic transport overflight (108.2 dBA) which was well above ambient noise levels (77.0 dBA). The number of gulls in flight after a subsonic aircraft overflight (91.8 dBA) did not differ from the number flying at normal colony noise levels. However, the threshold of response for nesting birds may be slightly higher than during other times in their annual cycle (i.e. non-breeding) (Dunnet 1977, Schrieber and Schrieber 1980, Murphy et al. 1986).

RESEARCH PLANS FOR 1988

The majority of work planned for 1988 will involve further data analysis. We have already collected data sets that are the integral components necessary to answer the primary objectives of this study but these data need further tabulation, analysis, write-up and synthesis into an energetic cost model of disturbance response. A brief listing of these component studies include: 1) annual cycle of body weight and composition of black brant, 2) review of literature on waterfowl energetic and foraging ecology of brant, 3) time and energy budget of undisturbed brant, 4) estimation of percent time spent in flight, 5) selection of food plants and foraging areas by brant, 6) factors influencing response to aircraft overflights, 7) brant response to natural and human-related disturbance, 8) characterization of sound levels and behavioral responses to aircraft overflights, and 9) determination of threshold levels of sound that cause response in brant.

Another area for future investigation is the importance of habituation to repeated exposure of the same or similar stimuli. Time and funding do not allow experimental evaluation of habituation at Izembek. However, we will examine existing data sets that were designed to ❑inimize habituation effects to assess the extent of habituation to aircraft overflights.

Field work in the fall of 1988 will emphasize collection of noise data generated by aircraft and behavioral responses of brant flocks to these aircraft. In 1987 we measured the total noise and maximum levels of aircraft overflights and correlated these data with the behavioral response of geese. However, the observed response occurred before maximum levels. In 1988 we plan to increase our sample size of noise recordings and to record the noise level at the time of response and more precisely define the threshold of response for brant. The microphone will be placed at the water surface and the observed response will be marked in the time series of 1/2 s acoustical data. This will facilitate better correlation between the observed response and the acoustical stimulus.

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b

LITERATURE CITED

Ankney, C. D. 1984. Nutrient reserve dynamics of breeding and molting brant. Auk 101:361-370.

Barsdate, R. J., M. Nebert, and C. P. McRoy. 1974. Lagoon contributions to sediment and water of the Bering Sea. In D. W. Hood, and E. J. Kelly, eds. Oceanography of the Bering Sea. Inst. Mar. Sci. Occas. Pub. No. 3, Univ. of Alaska, Fairbanks. 26pp.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Stackpole Books . Harrisburg, Pa. 540pp.

Berger, M., and J. S. Hart. 1974. Physiology and energetic of flight. Pages 415-477 in D. S. Farner, J. R. King, and K. C. Parkes, eds. Avian Biology Vol. IV. Academic Press, London. 504pp.

Black, B. B., M. W. Collopy, H. F. Percival, A. A. Tiller and P. G. Bohall. 1984. Effects of low level military training flights on wading bird colonies in Florida. Florida Coop. Fish and Wildl. Res. Unit. Tech. Rep. No. 7. Univ. of Florida. 190pp.

Blem, C. R. 1980. The energetic of migration. Pages 175-282 in S. A. Gauthreauy, Jr., ed. Animal migration, orientation, and navigation. Academic Press. 387pp.

Burger, J. 1981. Behavioral responses of herring gulls (Larus argentatus) to aircraft noise. Environ. Pollut. 24:177-184.

A

Child, G. I. 1969. A study of non-fat weights in migrating Swainson's thrushes (Hylocichla ustulatus). Auk 81:327-338.

Conant, B., J. I. Hodges, J. E. Sarvis, and C. P. Dau. 1984. Black brant population status workshop. Unpubl. Rep. U.S. Fish and Wildl. Serv. Cold Bay, Alaska. 11pp.

Conant, B. 1987. 1987 midwinter Pacific brant survey. U.S. Fish and Wildl. Serv. Memo. Juneau, Alaska. 3pp.

Chattin, J. E. 1970. Some uses of estuaries by waterfowl and other migratory birds. Pages 108-118 in Proc. N.W. Estuarine and Coastal Zone Symp., Portland, Oregon.

Davis, R. A., and A. N. Wisely. 1974. Normal behavior of snow geese on the Yukon-Alaska North Slope and the effects of aircraft-induced disturbance on this behavior, September, 1973. Pages 1-85 in W. W. H. Gunn, W. J. Richardson, R. E. Schweinsburg, and T. D. Wright, eds. Studies of snow geese and waterfowl in the Northwest Territories, Yukon Territory and Alaska, 1973. Arctic Gas Biol. Rep. Ser. 27. 85pp .

Denson, E. P., Jr. , and S. L. Murrell. 1962. Black brant populations of Humboldt Bay, California. J. Wildl. Manage. 26:257-262.

Derksen, D. V., M. W. Weller and W. D. Eldridge. 1979. Distributional ecology of geese molting near Teshekpuk Lake, National Petroleum Reserve-Alaska. Pages 189-207 in R. L. Jarvis and J. C. Bartonek, eds. Management and Biology of Pacific Flyway Geese. Oregon State Univ. Book Stores, Inc., Corvallis. 346pp.

Dunnet, G. M. 1977. Observations on the effects of low-flying aircraft at seabird colonies on the coast of Aberdeenshire, Scotland. Biol. Conserv. 12:55-63.

Ebbinge, B., A. St. Joseph, P. Prokosch, and B. Spaans. 1982. The importance of spring staging areas for arctic-breeding geese wintering in western Europe. Aquila 89:249-258.

Einarsen, A. S. 1965. Black brant: sea goose of the Pacific coast. Univ. of Washington, Seattle. 142pp .

Gabrielson, I. N. and F. C. Lincoln. 1959. The Birds of Alaska. Stackpole Books . Harrisburg, Pa. 922pp.

Grubb, M. M. 1978. Effects of increased noise levels on nesting herons and egrets. Proc. Col. Waterbird Group. 2:49-54.

Harrison, R. T., R. N. Clark, and G. H. Stanley. 1980. Predicting impact of noise on recreationists. U.S. Forest Serv., ED&T Proj. No. 2688. 32pp + app.

Hanson, H. A., and U. C. Nelson. 1957. Brant of the Bering Sea - migration and mortality. Trans. N. Am. Wildl. Conf. and Wildl. Manage. Inst., Washington, D.C. 19pp.

Henry, W. G. 1980. Populations and behavior of black brant at Humboldt Bay, California. Unpubl. M.S. Thesis, Humboldt State Univ., Calif. 111pp.

Izembek NWR 1986. 1986 Izembek NWR annual narrative reports. Unpubl. rep. U.S. Fish and Wildl. Serv., Cold Bay, Alas. 75pp.

Johnsgard, P. A. 1975. Waterfowl of North America. Indiana Univ. City Press. 575pp.

Jones, R. D. In prep. The avian ecology of Izembek Lagoon. Unpubl. rep. U.S. Fish and Wildl. Serv., Anchorage, Alas. 24pp .

Kramer, G. W., L. R. Rauen, and S. W. Harris. 1979. Populations, hunting mortality and habitat use of black brant at San Quintin Bay, Baja California, Mexico. Pages 242-254 in R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Book Stores, Inc., Corvallis. 346pp.

McRoy, C. P. 1966. Standing stocks and ecology of eelgrass (Zostera marina) at Izembek Lagoon, Alaska. M.S. Thesis, Univ. of Washington, Seattle, Wa. 138pp.

Murphy, S. M., B. A. Anderson, and C. L. Cranor. 1986. Lisburne terrestrial monitoring program - 1985. The effects of the Lisburne development project on geese and swans. Rep. prepared for ARCO Alaska, Inc., Anchorage, Alas., by Alaska Biological Research, Fairbanks Alas. 151pp.

Newman, J. S., E. J. Rickely, K. R. Beattie and S. A. Daboin. 1984. Noise measurement flight test: data/analyses Aerospatiale AS 355F TwinStar helicopter. U.S. Dept. Trans., Fed. Aviation Adm., Rep. No. FAA-EE-84-04. 103pp. + app.

Nisbet, I. C. T., W. H. Drury, and J. Baird. 1963. Weight loss during migration. Part I. Disposition and consumption of fat by the blackpoll warbler (Dendroica stirata). Bird Banding 34:107-138.

Owens, N. W. 1977. Responses of wintering brent geese to human disturbance. Wildfowl 28:5-14.

Sarvis, J. 1987. Black brant and emperor goose productivity and family group counts, Izembek NWR 1987. U.S. Fish and Wildl. Serv. Memo. Cold Bay, Alas. 4pp.

Schrieber, E. A. and R. W. Schrieber. 1980. Effects of impulse noise on seabirds of the Channel Islands. Pages 138-162 in J. R. Jehl, Jr., and C. F. Cooper, eds. Potential effects of space shuttle sonic booms on the biota and geology of the California Channel Islands. Cent. ' for Mar. Stud., San Diego St. Univ., Tech. Rep. 80-1.246pp.

Schwartzkopff, J. 1973. Mechanoreception. Pages 417-477 in D. S. Farner and J. R. King, eds. Avian biology Vol. III. Academic Press, New York. 573pp.

Schweinsburg, R. 1974. Disturbance effects of aircraft to waterfowl on North Slope lakes, June 1972. Pages 1-48 in W. W. H. Gunn, and J. A. Livingston, eds. Disturbance to birds by gas compressor noise simulators, aircraft and human activity in the Mackenzie Valley and the North Slope, 1972. Arctic Gas Biol. Rep. Ser. Vol. 14. 305pp.

Simpson, S. G., M. E. Hogan, and D. V. Derksen. In prep. Behavior and disturbance of molting Pacific black brant in arctic Alaska. Unpubl. rep. U.S. Fish and Wildl. Serv., Anchorage, Alas. 27pp.

Smith, R. H., and G. H. Jensen. 1970. Black brant on the mainland coast of Mexico. Trans. N. Am. Wildl. and Nat. Res. Conf. 35:277-241.

Stehn, R. A. 1987. Nesting success of geese in the coastal tundra region of the Yukon-Kuskokwim Delta: 1987 field report. Unpubl. rep. U.S. Fish and Wildl. Serv. Anchorge, Alas. 13pp.

U*S. Department of Commerce. 1987. Local climatological data: Annual summary with comparative data from Cold Bay, Alaska. 8pp.

Us. Department of Commerce. Summary of climatological data: Cold Bay, Alaska. 2pp.

Ward, D. H., R. A. Stehn, D. V. Derksen, C. J. Lensink, and A. J. Loranger. 1986. Behavior of Pacific black brant and other geese in response to aircraft overflights and other disturbances at Izembek Lagoon, Alas. Unpubl. Rep., U.S. Fish and Wildl. Serv., Anchorage, Alas. 33pp.

Ward, D. H., E. O. Taylor, M. A. Wotawa, R. A. Stehn, D. V. Derksen, and C. J. Lensink. 1987. Behavior of Pacific black brant and other geese in response to aircraft disturbances and other disturbances at Izembek Lagoon, Alaska. U.S. Fish and Wildl. Serv. Anchorage, Alas. 68pp.

APPENDIX A

SPECIFICATION FOR MODEL 4921 MICROPHONE

SIGNAL INPUT

Microphone:	Quartz-coated 1/2″ condenser microphone
Frequency Response	
Amplifier:	20 Hz to 20 kHz ±1 dB
Acoustical System:	In accordance w/IEC 651 Type 1 (free field 0° incidence), 20 Hz to 10 kHz: +1 dB, -2 dB, 20 Hz to 20 kHz: +1 dB, -4 dB
Dynamic Range:	Lower limit (5 dB above noise) 40 dBA with external filter 40 dBA with built-in filter Upper limit (3% distortion) 160 dB
Amplification by the ZZ 0035:	60 dB in five 10 dB steps plus 10 dB continuously adjustable
Output Impedance	
From Preamplifier:	<50 ohms
From Amplifier:	<1 ohm
From Transformer:	50 or 200 ohms
Weighting:	A-weighting in accordance w/IEC 651
Calibration:	Built-in electrostatic actuator gives 90 dB at 1 kHz (initiated by push button on the ZZ 0035 or from some remote station)

ENVIRONMENTAL

Dehumidifier:	Contains 75 g of silica gel which should give protection for approximately 3 years.

<u>Humidity Range</u>: O to 100% relative humidity

<u>Temperature Range</u>: -25 to 70" C (-13 to 158° F)

POWER

<u>Internal Batteries</u>: 8 x 1.5 V IEC LR20 (D cells) approximately 120 h continuous operation. Ordinary dry batteries give about 30 h continuous operation.

<u>Internal Power Supply ZG 0085</u>: Delivers 12 V from main supplies 100 to 240V. 50 to 400 Hz

<u>External Batteries</u>: 8 to 12 V. 100 mA consumption

<u>B & K Microphone Power Supply</u>: Connects to preamplifier and by-passes ZZ 0035

<u>Mechanical</u>:

Height:	1262 mm
Width:	200 mm
Depth:	110 mm
Weight:	7.6 kg

APPENDIX B

SPECIFICATIONS FOR MODEL 3100 REAL TIME ANALYZER

SIGNAL INPUT SECTION

Microphone Conditioned Input

Impedance:	10 G ohm // 2.0 pf
Polarization:	200-28-0 volts
Gain:	-30 to 90 dB, 10 dB steps
Sensitivity:	Keyboard input (nonvolatile)
Frequency Range:	1 Hz to 100 KHz

Direct AC Input

Impedance:	1 M ohm // 47 pf
Gain:	-30 to 90 dB, 10 dB steps
Sensitivity:	Keyboard input (nonvolatile)
Frequency Range:	1 Hz to 100 KHz
Full Scale Ranges:	100 UV to 10 Vac calibrated rms

Preselect Filters

Characteristics:	Digitally selected 3-pole high-pass and low-pass filters to enhance dynamic response of analyzer
High Pass Frequencies:	1, 5, 10, 20, 50, and 100 Hz
Low Pass Frequencies:	1, 3.15, 10, 20, 31.5, and 100 KHz

DETECTOR SECTION

Detector Characteristics

Response:	True rms detection of filter outputs
Resolution:	0.1 dB
Dynamic Range:	70 dB
Display Range:	>60 dB
Crest Factor:	10 dB above full scale increasing to 70 dB at bottom scale
Linearity Error:	±0.2 dB over full scale
Linear Average:	0.1 sec to 99 hrs in 0.1 sec increments
Exponential Average:	1/8 sec to 128 sec in binary sequence

Detector Types

Linear Average:	0.1 sec to 99 h in 0.1 sec increments
Exponential Average:	1/8 sec to 128 sec in binary sequence
Transient Average:	10 msec time constant w/100 spectra/see storage rate

FILTER SECTION

Bandpass Filters

1/3 Octave BW:	All filters exceed the requirements of ANSI S1.11-1966 Class III, IEC 225-1966, DIN 45 652-1964, BS2475-1964
1/1 Octave BW:	All filters exceed the requirements of ANSI S1.11-1966 Class II, IEC 225-1966, DIN 45 652-1964, BS2475-1964

Broadband Filters

Weighting Networks:	A, C, and Lin filters meet ANSI S1.4-1983, IEC 651-1979 DIN 45633, BS4197-1967 for Type 1 Sound Level Meter

DISPLAY SECTION

Internal Display

Type:	Flat panel LCD screen
Size:	6.6 x 23.6 cm
Resolution:	128 x 480 with full graphics and alphanumerics
Contrast:	Adjustable dark to full sunlight
Range:	80 dB

OUTPUT/CONTROL SECTION

Digital

Printer Out:	A parallel printer output port is provided for printing displayed or stored data (does not require use of a remote computer)
Optional Computer Interfaces:	IEEE-48B, RS-232 and HP-IL

Analogue

AC Out:	1 volt rms signal output for a full scale input to the preamplifier. Output impedance is 100 ohms .

POWER SECTION

Line Power

Model 3100:	Operates continuously from 120 volts, 60 Hz, 230 volts, 50 Hz at 10 VA
Internal Battery:	Rechargeable power pack will operate the analyzer continuously for more than 8 h.
External DC Input:	An external source of filtered DC power in the range of 12-30 Vdc will power the Model 3100 continuously. Power requirement is less than 8 VA.

ENVIRONMENTAL

Operating Temp. Range:	0 to 50 degrees C
Storage Temp. Range:	-20 to +60 degrees C
Humidity: (Non-condensing)	+ 90% RH

MECHANICAL

Height:	15.2 cm
Width:	36.2 cm
Depth:	36.2 cm
Weight:	Approximately 11.3 kg w/batteries